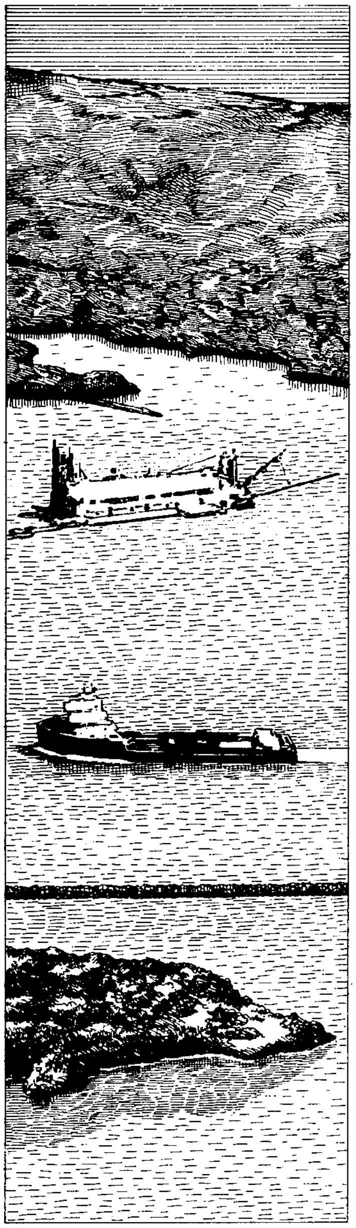
US Army Corps of Engineers



DREDGING RESEARCH PROGRAM

TECHNICAL REPORT DRP-94-6

IMPROVED EDUCTORS FOR SAND BYPASSING

by

G. L. Williams, J. E. Clausner, P. J. Neilans

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

November 1994

Final Report

Approved For Public Release; Distribution Is Unlimited

Prepared for DEPARTMENT OF THE ARMY
U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Work Unit 32474

The Dredging Research Program (DRP) is a seven-year program of the US Army Corps of Engineers. DRP research is managed in these five technical areas:

- Area 1 - Analysis of Dredged Material Placed in Open Waters
- Area 2 - Material Properties Related to Navigation and Dredging
- Area 3 - Dredge Plant Equipment and Systems Processes
- Area 4 - Vessel Positioning, Survey Controls, and Dredge Monitoring Systems
- Area 5 - Management of Dredging Projects

PRINTED ON RECYCLED PAPER

US Army Corps of Engineers
Waterways Experiment Station

Dredging Research Program Report Summary

Improved Eductors for Sand Bypassing (TR DRP-94-6)

ISSUE: The effectiveness of eductor (jet pump) fixed plant bypassing systems is often reduced by the presence of debris, which reduce the system production rate. Debris can also make installation and recovery of eductors more difficult. Eductor improvements that increase production in various types of debris and make installation and removal more easily accomplished are desirable.

RESEARCH: A DRP-developed eductor with several features to improve debris resistance was field tested at the Indian River Inlet, Delaware, sand bypass plant. Production parameters including slurry velocity, percent solids, production rate, slurry specific gravity, supply pump pressure, booster pump suction, booster pump pressure, and supply pump suction were measured for the DRP eductor as well as the existing Indian River Inlet (IRI) eductor. These parameters were used to evaluate the DRP eductor performance versus the IRI eductor.

SUMMARY: Overall average production rates were 389 yd^3/hr (297.4 m^3/hr) and 350 yd^3/hr (267.6 m^3/hr) for the DRP and IRI eductors, respectively, indicating increased production of about 11 percent for the DRP eductor. Other production and operating parameters were examined to determine which operating factors may have had an influence on production. Physical/operational parameters of each eductor were also examined to address the reasons for the increased production of the DRP eductor.

AVAILABILITY OF REPORT: The report is available on Interlibrary Loan Service from the U.S. Army Engineer Waterways Experiment Station (WES) Library, telephone (601) 634-2355. National Technical Information Service (NTIS) report numbers may also be requested from the WES librarians.

To purchase a copy, call NTIS at (703) 487-4650.

About the Authors: Messrs. Gregory L. Williams, James E. Clausner, and Peter J. Neilans are all members of the Coastal Engineering Research Center at the U.S. Army Engineer Waterways Experiment Station.
Point of Contact: Mr. James E. Clausner, Principal Investigator for this work unit. For further information about the DRP, contact Mr. E. Clark McNair, Jr., Manager, Dredging Research Program at (601) 634-2020.

Technical Report DRP-94-6
November 1994

Improved Eductors for Sand Bypassing

by G. L. Williams, J. E. Clausner, P. J. Neilans

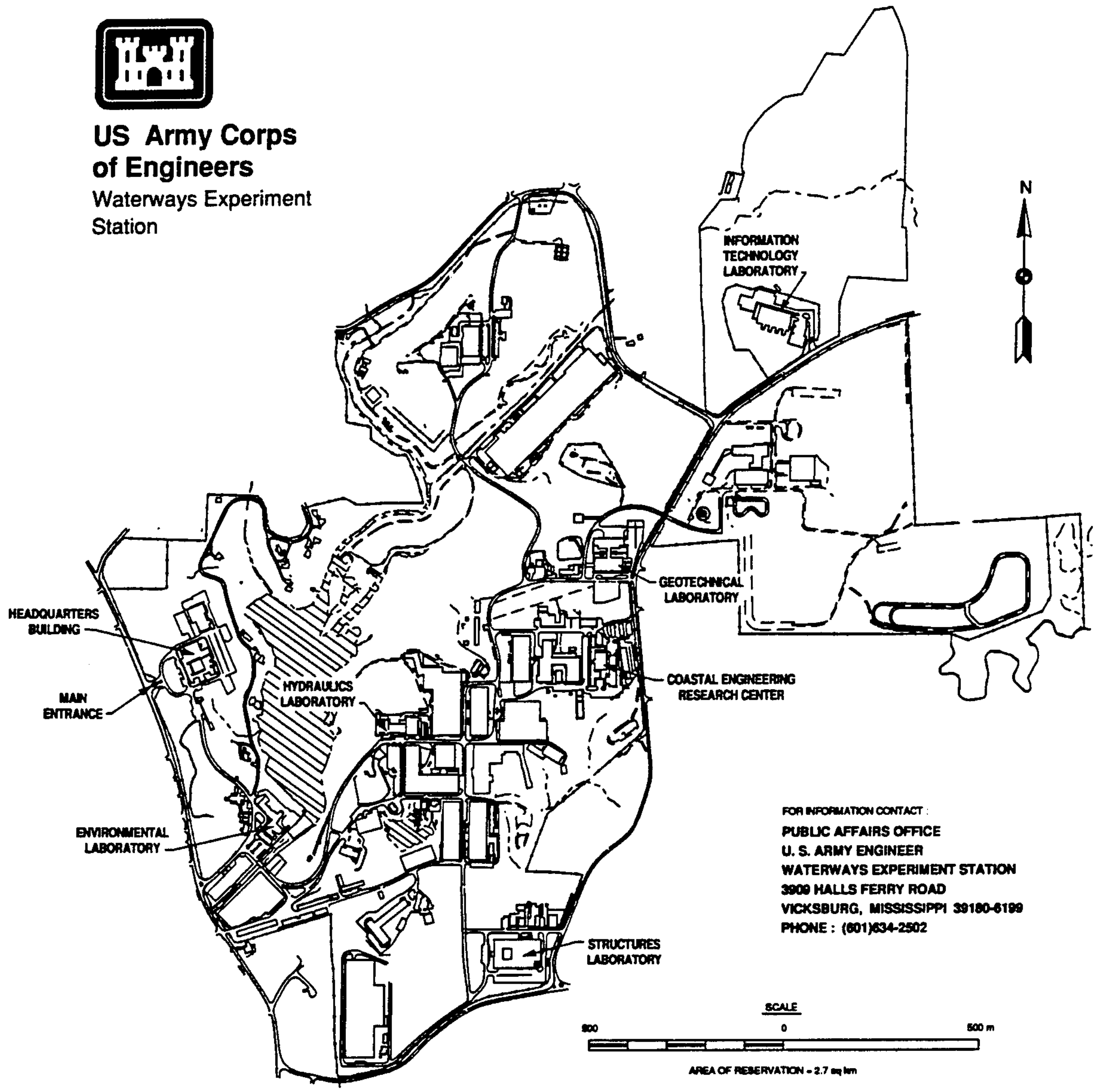
U.S. Army Corps of Engineers
Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final report

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Work Unit No. 32474

US Army Corps of Engineers
Waterways Experiment Station



Waterways Experiment Station Cataloging-in-Publication Data

Williams, Gregory L.
Improved eductors for sand bypassing / by G.L. Williams, J.E. Clausner, P.J. Neilans ; prepared for U.S. Army Corps of Engineers.
44 p. : ill. ; 28 cm. — (Technical report ; DRP-94-6)
Includes bibliographic references.
1. Ejector pumps — Design and construction. 2. Dredging — Equipment and supplies. 3. Pumping machinery — Performance. I. Clausner, James E. II. Neilans, Peter Jay. III. United States. Army. Corps of Engineers. IV. U.S. Army Engineer Waterways Experiment Station. V. Dredging Research Program. VI. Title. VII. Series: Technical report (U.S. Army Engineer Waterways Experiment Station) ; DRP-94-6.
TA7 W34 no.DRP-94-6

Contents

Preface

This study was authorized as part of the Dredging Research Program (DRP) of Headquarters, U.S. Army Corps of Engineers (HQUSACE), and performed under the Improved Eductors for Sand Bypassing Work Unit 32474, which is part of Technical Area 3, Dredge Plant Equipment and Systems Processes. Messrs. Robert Campbell and Gerald Greener were DRP Chief and Technical Area 3 Monitor, respectively, from HQUSACE. Mr. E. Clark McNair, Jr., Coastal Engineering Research Center (CERC), U.S. Army Engineer Waterways Experiment Station (WES), was DRP Program Manager (PM), and Dr. Lyndell Z. Hales, CERC, was Assistant PM. Mr. William D. Martin, Chief, Estuarine Engineering Branch, Estuaries Division, Hydraulics Laboratory, was the Technical Manager for Technical Area 3 during the conduct of the study. This study was performed and the report prepared over the period July 1991 to January 1994 by Messrs. James E. Clausner, Peter J. Neilans, and Gregory L. Williams. Messrs. Clausner, Neilans, and Williams were under the administrative supervision of Dr. Yen-hsi Chu, Chief, Engineering Applications Unit, Coastal Structures and Evaluation Branch, Engineering Development Division (EDD), CERC. Mr. Thomas W. Richardson was Chief, EDD, CERC. Dr. James R. Houston was Director, CERC, and Mr. Charles C. Calhoun, Jr., was Assistant Director, CERC.

Dr. Robert W. Whalin was Director of WES during the preparation of this report. COL Bruce K. Howard, EN, was Commander.

Summary

Eductors have been used as the sand removal device for bypass systems for two decades. The effectiveness of eductor (jet pump) fixed plant bypassing systems is often reduced by the presence of debris, which reduce the system production rate. Debris can also make installation and recovery of eductors more difficult. Eductor improvements that increase production in various types of debris and make installation and removal easier are desirable.

This report describes an eductor developed under the Dredging Research Program (DRP) with several features to improve debris resistance (grates, fluidizers) and the results of a field test comparing production from it and an existing eductor at the Indian River Inlet (IRI), Delaware, sand bypass plant. This plant uses a single eductor deployed from a crawler crane to mine the updrift fillet. The eductor used at the IRI bypass plant was designed and manufactured by Genflo America and has nearly identical nozzle, mixer, and diffuser dimensions as the DRP eductor. As such, it provided an excellent baseline for evaluating improvements made in the DRP eductor.

The IRI site is not ideally suited to fully test the design features of the DRP cased eductor. The bypass plant at IRI is neither fixed (the condition for which the DRP eductor was designed) nor does it have a significant debris problem. However, the IRI site had a number of attractive features including compatible hydraulics (pressure, flow rate, pipeline diameters), an adaptable deploying crane, and existing instrumentation.

Both eductors were tested and data collected on slurry velocity, percent solids, production rate, slurry specific gravity, supply pump pressure, booster pump suction, booster pump pressure, and supply pump suction. These data were then used to calculate hourly production rates that were used for comparison between the eductors. Overall average production rates show that the DRP eductor performed 11 percent better than the IRI eductor (389 yd^3/hr (297.4 m^3/hr) versus 350 yd^3/hr (267.6 m^3/hr)). Operational influences during test runs and physical characteristics of each eductor were examined to evaluate all potential factors affecting production.

1 Introduction

Bypassing Background

Interruptions in the shoreline (e.g. inlets and harbors), particularly those with stabilizing structures such as jetties, trap sand moving alongshore. Sand trapped in entrance channels often makes navigation difficult. Sand trapping in accretion fillets and interior and exterior shoals frequently causes downdrift beach erosion. Artificial sand bypassing (referred to as bypassing in the remainder of this report) is the man-induced transfer of trapped sand across inlets and harbors to assist in maintaining navigable entrances and prevent downdrift beach erosion.

While the majority of sand bypassing is done with conventional dredges (U.S. Army Corps of Engineers (USACE) 1991), fixed bypass plants have been used in the United States since the 1930's (Jones and Mehta 1980). These early fixed bypass plants used conventional dredge pumps operating through a suction snout from a pivoting turret attached to the updrift jetty (Watts 1962). In the 1970's the U.S. Army Engineer Waterways Experiment Station (WES) investigated using eductors (also known as jet pumps) for sand bypassing (McNair 1976), culminating in an instruction report on eductor bypass system design (Richardson and McNair 1981). During the late 1970's and the early 1980's a limited number of eductor-based bypass plants operated on the U.S. east and gulf coasts. However, debris often reduced production rates, and difficulties in deploying and retrieving the eductors limited effectiveness.

In 1986 a large bypass plant was constructed at the Nerang River Entrance in Southport, Queensland, Australia (Clausner 1988). This plant uses 10 eductors spaced at 100-ft (30.48-m) intervals along a pier extending through the surf zone, and has effectively bypassed large quantities of sand (in excess of 500,000 yd^3/year (382,000 m^3/year)). However, even in this innovative plant, the operators experienced significant debris problems which often exacerbated difficulties retrieving the eductors.

In 1988, USACE started the Dredging Research Program (DRP), a 7-year, multi-million-dollar research effort aimed at saving federal dredging dollars. Less than fully successful U.S. eductor bypassing efforts, along with the

success and problems at the Nerang River Entrance Bypass Project, led to the creation of the "Improved Eductors for Sand Bypassing" Work Unit as part of the DRP. The goal of the work unit was to design an eductor (referred to as the DRP eductor for the remainder of the report) that would maintain good performance in various types of debris and would also be more easily deployed and retrieved when used as part of a fixed bypass plant.

Related Research

As the eductor investigations progressed, suggestions were made to consider other options for fixed plant bypassing. Submersible pumps (small centrifugal pumps placed directly in the sediment to be bypassed) appeared to offer several positive features that made them potentially attractive as eductor alternatives. Thus one facet of the work unit investigated the potential for using submersible pumps for sand bypassing. Clausner, Patterson, and Rambo (1990) describe the general characteristics of submersible pumps. Neilans et al. (1993) discuss the successful application of a submersible pump for dredging around locks on the Red River.

Another way of improving bypassing with fixed eductors is to expand the area of eductor influence, i.e. to increase the area over which sand is trapped, by using fluidizers. Fluidizers are perforated pipes through which water is pumped under pressure, causing the overlying sand to liquify and flow down mild slopes. Fluidizers create trenches which increase the volume of sand available to the eductor for bypassing. To complement the eductor research, additional research to define fluidizer hydraulics was also funded by the work unit. Weisman, Lennon, and Clausner (1992, 1994) summarize hydraulic design of fluidizers. Bisher and West (1993) describe a successful application of fluidizers to the eductor-based bypass plant at Oceanside, CA.

DRP Eductor Development

The DRP eductor developed under this work unit was designed to reduce the impact of debris and deployment problems described previously. A number of mechanical and hydraulic devices were considered to solve the problems mentioned. The final configuration selected was designed to have the best combination of debris resistance, ease of installation, and simplicity of design and operation.

The DRP eductor was developed under contract to Genflo America. Included in the contract were conceptual design, detailed design, construction, controlled comparison tests, and field tests.

Following construction of the DRP eductor, it and the Genflo eductor used at the bypass plant at Indian River Inlet (IRI), Delaware, were tested under controlled conditions in a gravel pit in Louisiana (Clausner, Welp, and Bishop

1993; Clausner et al. 1994) in both clean sand and various debris combinations. Two commercially available submersible pumps were also tested under the same conditions. The control tests in Louisiana showed both eductors have nearly equal performance in clean sand, with the DRP eductor performing better in debris made up of stones, garbage bags, and swim fins, while the IRI eductor performed better in wood debris. The submersible pumps were both effective, with one of the pumps outperforming the eductors. However, both submersible pumps were susceptible to clogging and required constant operator adjustment.

The final part of the DRP eductor development was to perform a long-term field test of the eductor at an existing sand bypassing plant to determine production rates, influence of debris, and to a limited extent, deployment capabilities. Tests were conducted at the IRI bypass plant. The plant, which started bypassing operations in January 1990, was constructed and is operated under a cost-sharing agreement between the U.S. Army Engineer District, Philadelphia (CENAP) and the State of Delaware. This plant uses a single eductor deployed from a crawler crane to mine the updrift fillet. The eductor used at the IRI bypass plant was designed and manufactured by Genflo America and has nozzle, mixer, and diffuser dimensions nearly identical to the DRP eductor. As such, it provided an excellent baseline for evaluating improvements made in the DRP eductor, both in the controlled tests conducted in 1991 and in the tests described in this report.

The IRI site is not ideally suited to fully test the design features of the DRP cased eductor. The best possible site would have been one with fixed eductors (similar to Nerang) with some debris. No such plant exists in the United States. The bypass plant at Indian River Inlet is neither fixed, nor does it have a significant debris problem. However, the only other Corps fixed bypass plant in the United States, located at Oceanside, CA, was not compatible with the DRP Genflo eductor requirements for pressure or flow (Moffatt and Nichol Engineers 1990). Also, the crane deployment scheme at Indian River Inlet did not allow the designed deployment scheme for the DRP eductor to be fully tested.

Though not ideal, the Indian River Inlet site had a number of attractive features in addition to being the only one suited for this test. First, the hydraulics (pressure, flow rate, pipeline diameters) were compatible with the DRP eductor. Also, the crane used to deploy the IRI eductor was also capable of deploying the DRP eductor. The level of instrumentation was sufficient for the tests. And last, but not least, the State of Delaware staff overseeing and operating the bypass plant were both skilled and cooperative.

Following this introduction are brief descriptions of eductors in general, and the DRP and IRI eductors. A discussion of the Indian River Bypass Plant follows. Next are sections on how the tests were run, and how data were collected. Subsequently, how the data were analyzed and the results of the analysis are provided, followed by both specific and general conclusions. Finally, general recommendations not specifically related to these tests are

included on the DRP eductor, eductor-based bypassing, and potential applications of submersible pumps.

2 Eductors

Hydraulics

Eductors are hydraulic pumps with no moving parts (Figure 1). They operate by using a supply (motive) water pump to provide a high pressure flow at the eductor nozzle. As the jet contacts the surrounding fluid, momentum is exchanged in the mixer where the jet slows and the surrounding fluid is accelerated, thus entraining additional fluid into the jet. As the surrounding fluid is entrained by the jet, it pulls in additional fluid from outside the eductor. Placing an operating eductor in saturated sand allows it to entrain a sand/water slurry. Often some of the supply water is diverted to fluidizing nozzles to increase the flow of sand to the eductor. In the diffuser, the excess jet velocity is converted back into sufficient fluid pressure to allow system operation with appropriate hydraulic conditions.

One advantage of a pump with no moving parts (i.e. an eductor) is the ability to submerse it in the fluidized material to be pumped. Eductors can also be started after being completely buried in sand, a requirement for most fixed bypassing plants. These factors allow for convenient deployment as well as helping to reduce the effective suction line length when used in conjunction with a centrifugal pump.

Another advantage of properly designed eductors over conventional centrifugal pumps is that they are essentially immune to causing blockages in the discharge line. This can briefly be described as follows. As the discharge line starts to clog through sediment deposition, the effective cross-sectional area of the discharge line is reduced, thereby causing an increase in pressure. When the eductor is forced to work against an increase in pressure, the amount of material the eductor will entrain is reduced. Therefore the eductor automatically pumps less solids, reducing the potential for clogging the pipe. This is true even when the eductor is used in a hybrid combination where the eductor discharges directly to the suction line of a centrifugal pump. A more detailed description of this phenomenon is given by Wakefield (1992). A practical test of the hybrid combination is discussed in Wakefield (1993, 1994) where a jet pump (eductor) is shown to contribute little to head, energy, and flow, but overall pipeline stability (from clogging) was maintained.

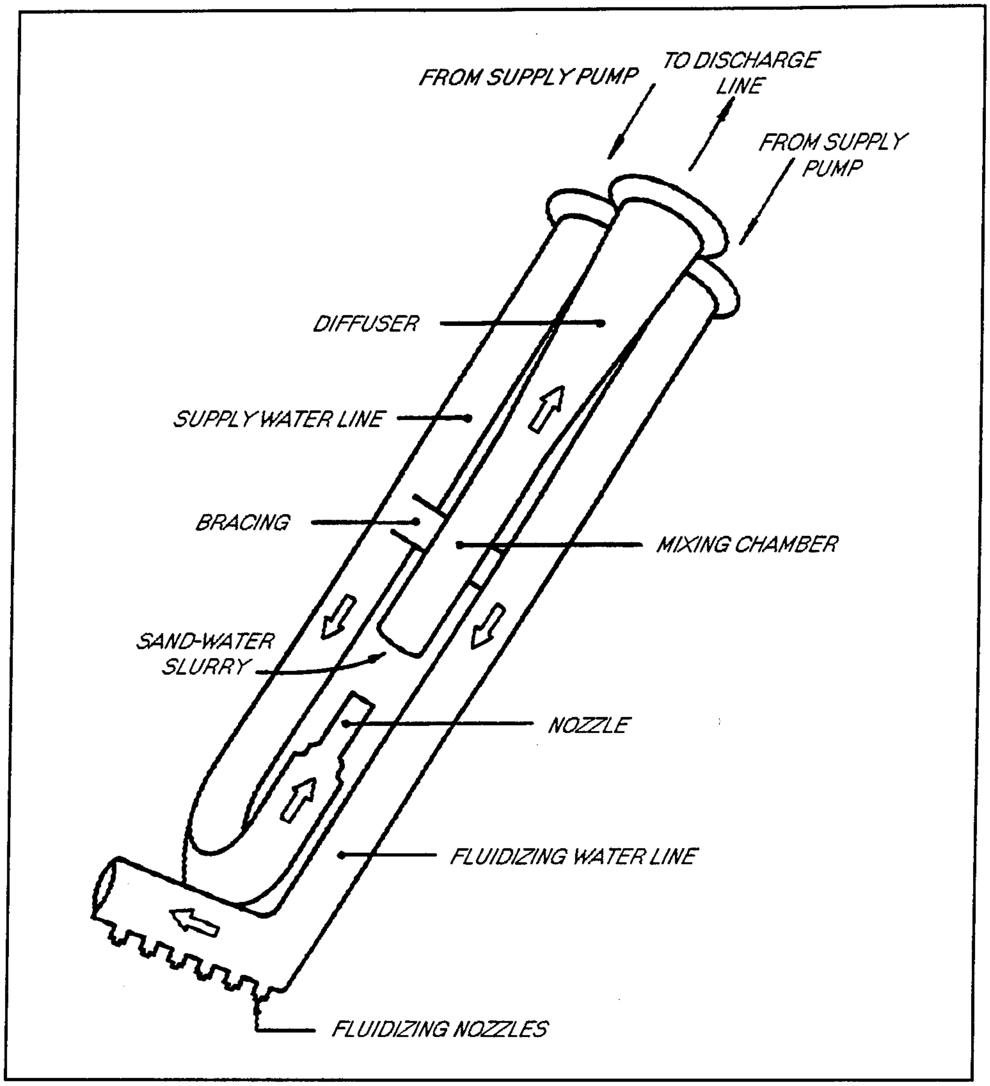


Figure 1. Eductor

One problem experienced with eductors in general and in particular at the Nerang River Entrance Project in Australia is debris problems causing eductor blocking or clogging. The standard method of handling debris at a plant with fixed eductors (i.e. eductors that are not readily removed) is to backflush, blocking the discharge line and thus forcing the supply water out through suction ducts. This hopefully will also flush out the debris. However, in areas with considerable amounts of debris, the backflushing requirement can become so frequent that it becomes impractical. Therefore, the ability to operate effectively in areas with debris is important and was the driving force behind the DRP eductor development.

Some of the design features of the DRP eductor include (Figure 2):

a. A smooth cylindrical outer shape to prevent debris (logs and sticks) from jamming in the eductor framework and making retrieval difficult.

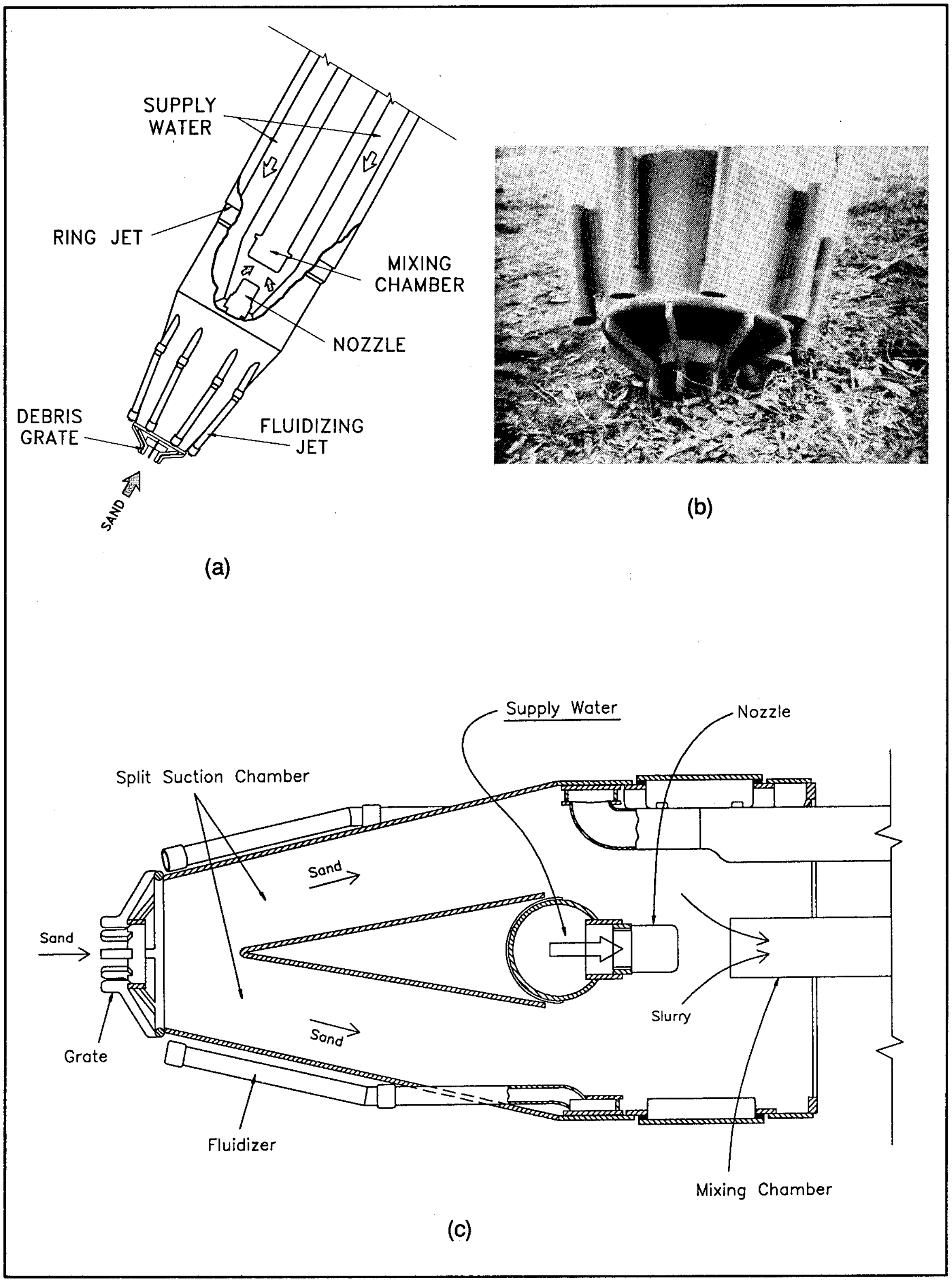


Figure 2. DRP eductor

b. A series of fluidizing nozzles around the perimeter of the tip to fluidize the sand for removal and to allow heavy debris to sink below the eductors.

c. A grate over the entrance to prevent debris from entering the suction chamber.

d. A split suction chamber that expands in cross-sectional area (Figure 2c).

The IRI eductor, also manufactured by Genflo (and very similar to the eductors used at Nerang) has the same basic hydraulic components as the DRP eductor, with an identical mixer diameter of 150 mm (6 in.). The DRP eductor has a slightly larger nozzle, 70 mm, compared with the IRI nozzle of 65 mm. This eductor has a simple annular suction duct, shroud, and a linear manifold of fluidizing nozzles (Figure 3).

Deployment/Retrieval

An important aspect of effectively using an eductor for sand bypassing is easy deployment and retrieval. As noted earlier, the DRP eductor was designed for use in a fixed plant, specifically vertical insertion from a pier. The contractor realized that during its life (particularly during testing), the DRP eductor would also be deployed on the dry beach as part of a semi-mobile bypass system. While a large crane is capable of holding the DRP eductor vertically, the contractor considered the potential that the eductor could be deployed from a truss/roller combination with an arched boom. This combination could be less expensive than a large crane. However, to allow such a deployment scheme to work, the eductor would need to be rolled along the beach, be stable when in operation, and create a crater in a location that would not endanger the deployment equipment. The contractor's solution to these problems is the eductor/deployment truss/roller combination shown in Figure 4.

This combination forms an inherently stable three-legged stool that allows the eductor to pivot downward as it excavated its crater without tipping over on its side. Also, the length of the middle truss section is sufficient that the crater with 1:1.5 side slopes will not reach the pivot point.

Due to the additional costs associated with construction of the platform (including winches and cables), and the requirement to have the crane available for deploying the IRI eductor and the submersible pumps, the full truss/roller and eductor/arched boom concept using only winches for deployment was never tested. For both the comparative tests in Louisiana and these tests at Indian River Inlet, the truss/roller and eductor/arched boom were deployed with a large crane.

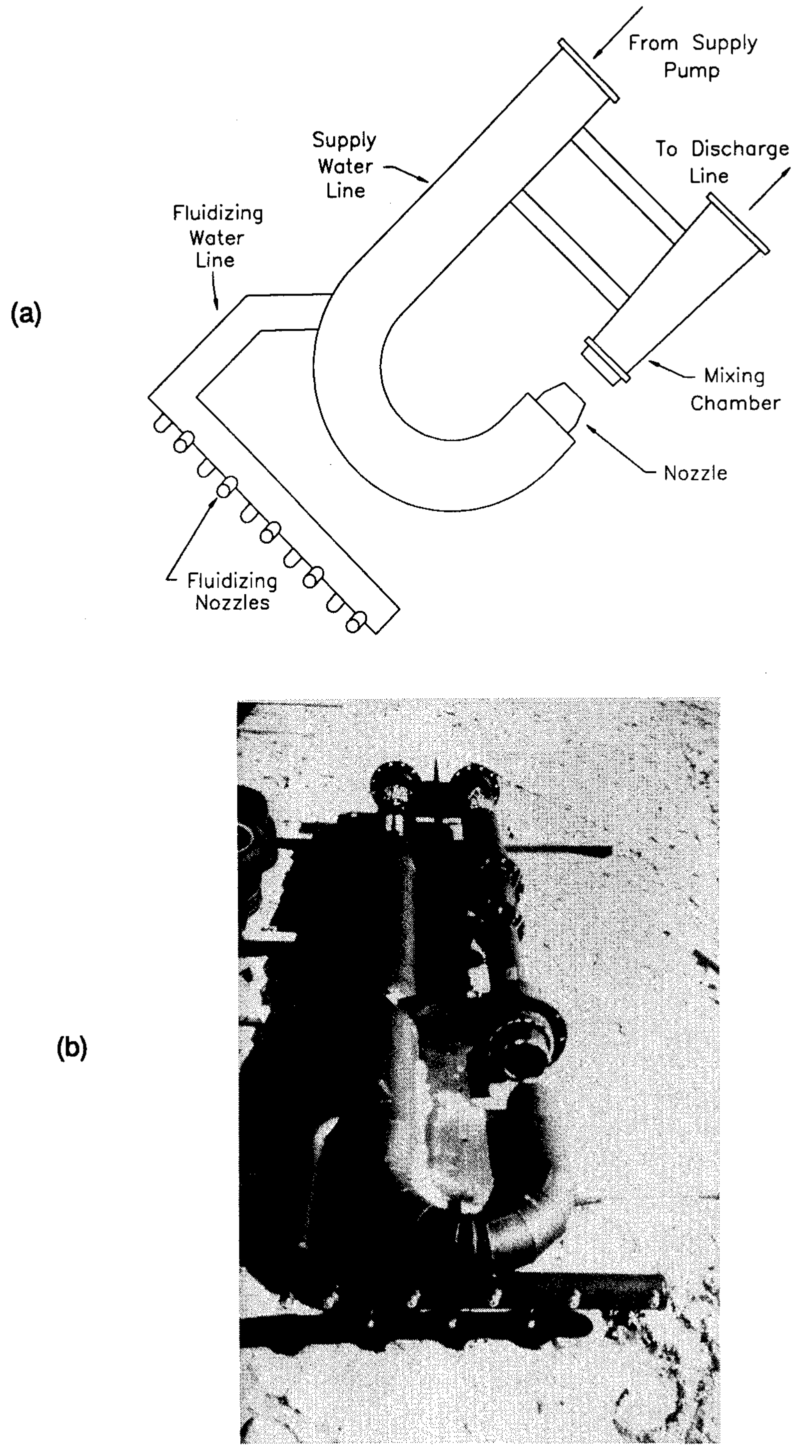


Figure 3. IRI eductor

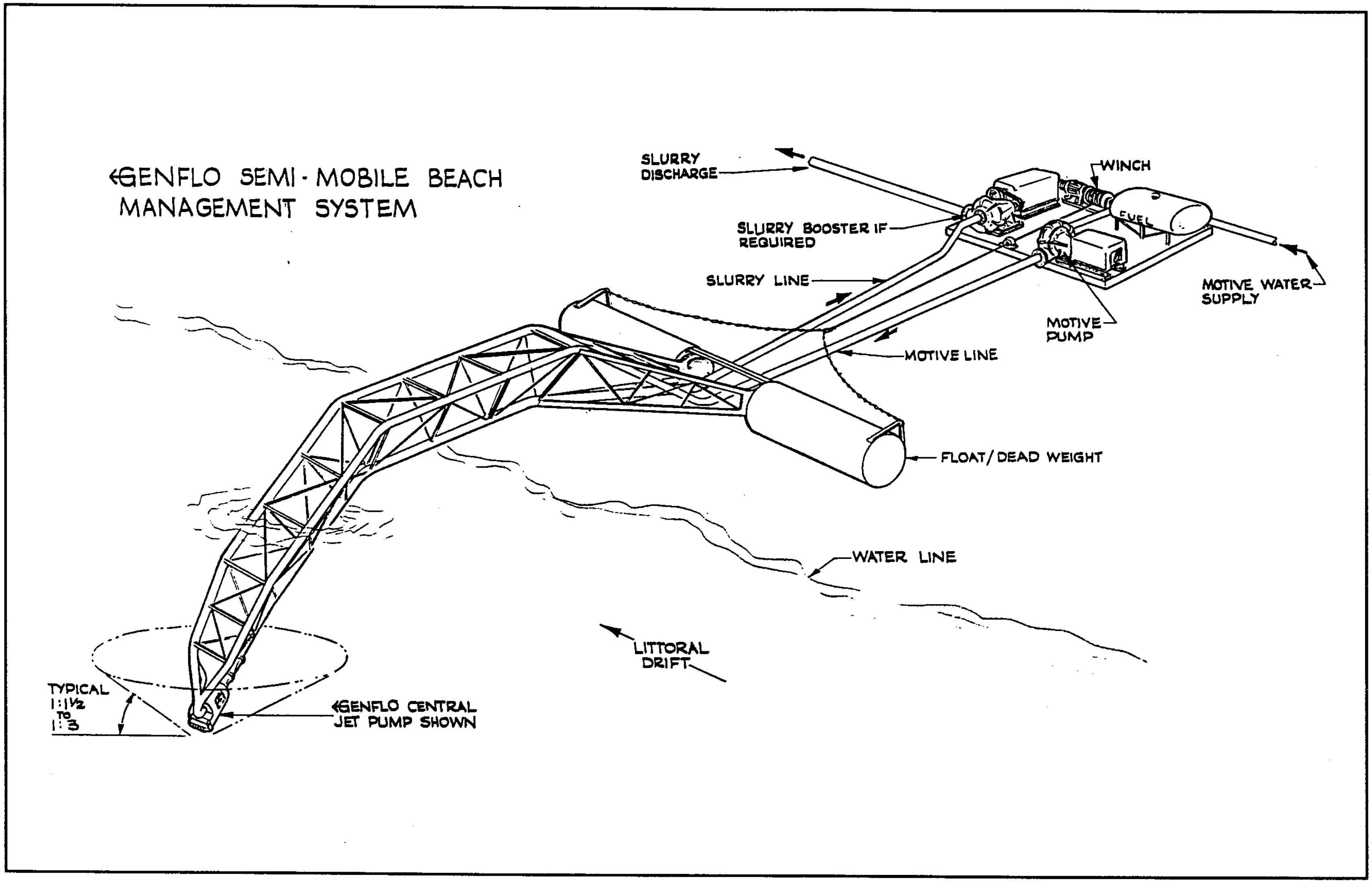


Figure 4. Semi-mobile eductor truss/roller conceptual design

3 Testing - Site Characteristics and Procedures

The IRI bypass plant is a unique fixed bypass plant. To provide the reader with some perspective on the plant, some background on the facility is provided initially. Specific details on the site and testing procedures as related to the effort are provided in this section.

IRI Bypass Plant

Indian River Inlet, Delaware, is located on the Atlantic coast, approximately 10 miles (16.1 km) north of Ocean City, MD (Figure 5). The shallow, meandering inlet at the site was improved in the late 1930's to provide a more reliable conduit of fresh water for the bay. Soon after construction, the 500-ft-wide (152.4-m-wide) twin-jettied inlet began to show the classic updrift accretion and downdrift erosion pattern associated with a net sediment transport in one direction. By the mid-1950's beach nourishment was required for the downdrift (north) beach. The erosion problem was acerbated when a new bridge over the inlet was constructed closer to the shore in the 1960's. Since then, periodic beach nourishment has been required to protect the Delaware Highway 1 bridge approach on the north side of the inlet.

A study conducted by CENAP in 1986 concluded that a fixed sand bypass plant was a more economical means of protecting the bridge approach than a revetment or dredging (Rambo and Clausner 1989). The final design selected consists of an eductor deployed from a crawler crane along a 500-ft-long (152.4-m-long) stretch of beach just south of the south jetty.

The supply and booster pumps are contained in a pump house located behind the primary dune on the south side of the inlet. The supply pump draws clean water from the inlet and provides it to the eductor through a high-density polyethylene (HDPE) 10-in. (25.4-cm) supply line. The eductor is deployed by a crawler crane on the beach face between the high and low water line. Slurry discharge from the eductor flows to the booster pump via

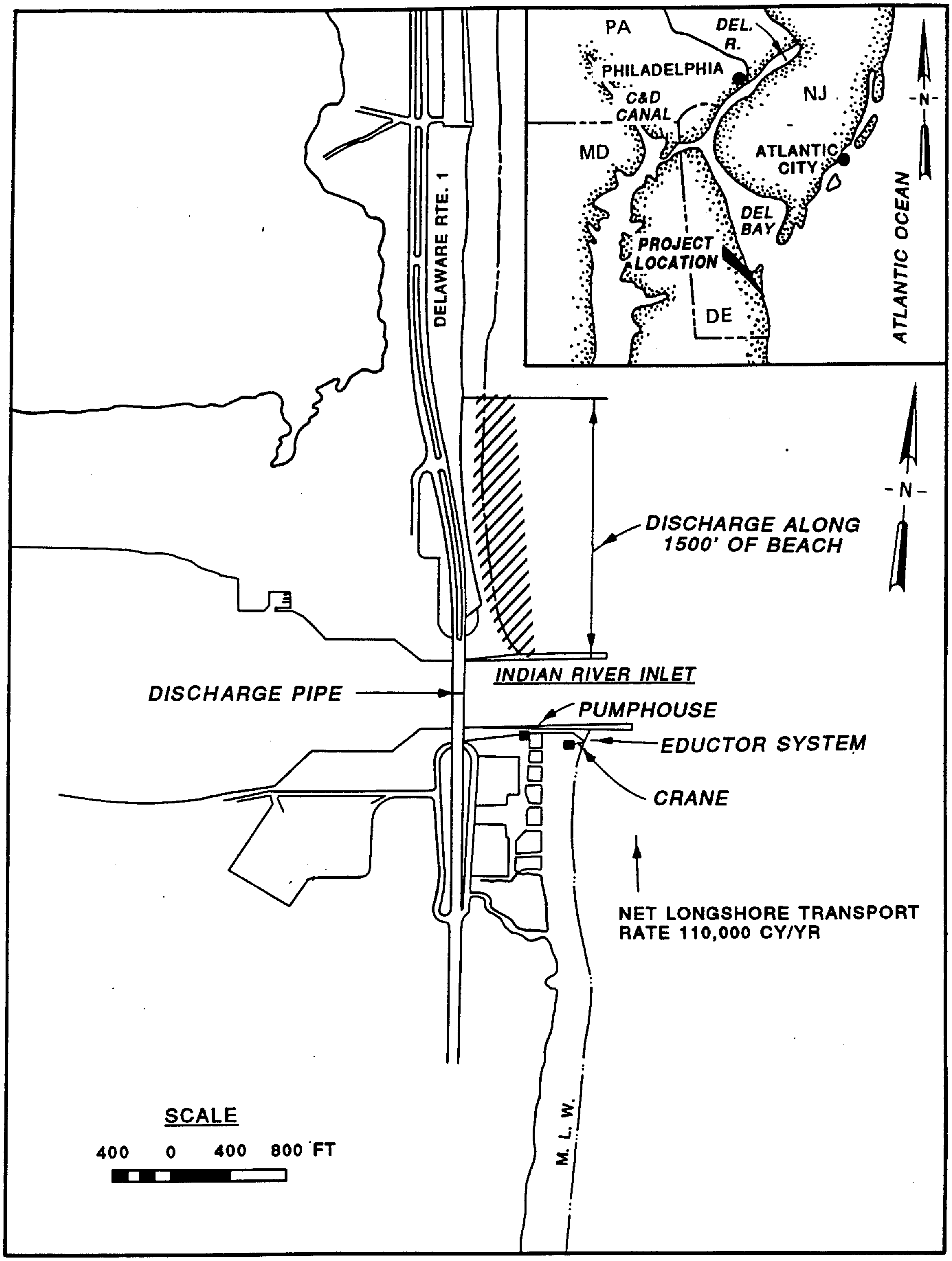


Figure 5. Indian River Inlet location map

an 11-in. (27.9-cm) HDPE line. The slurry is then pumped across the Route 1 bridge to the north side of the inlet. Maximum discharge pipeline length from booster pump to discharge point is 1,500 ft (457.2 m). Details of each of the system components are listed in Table 1. A schematic of the system layout is shown in Figure 6.

Table 1
System Components (Clausner, Patterson, and Rambo 1990)

Component	Manufacturer/Type	Capacity
Supply pump	Gould 3410-L powered by 8-cyl diesel	320 hp @ 400 ft head and 2,500 gpm (238.6 kW @ 1195.6 kPa and 567.81 cu m/hr)
Crane	Manitowoc 3900WV	135 tons (137.2 metric tons) with 120-ft boom (36.6-m boom)
Eductor	Genflo	2.5-in. nozzle, 6-in. mixing chamber, 200 cyl/hr (6.35-cm nozzle, 15.2-cm mixing chamber, 152.9 cu m/hr)
Booster pump	Pekor 32MX powered by 12-cyl diesel	330 hp @ 276 ft head and 3,200 gpm (246.1 kW @ 824.96 kPa and 726.8 cu m/hr)

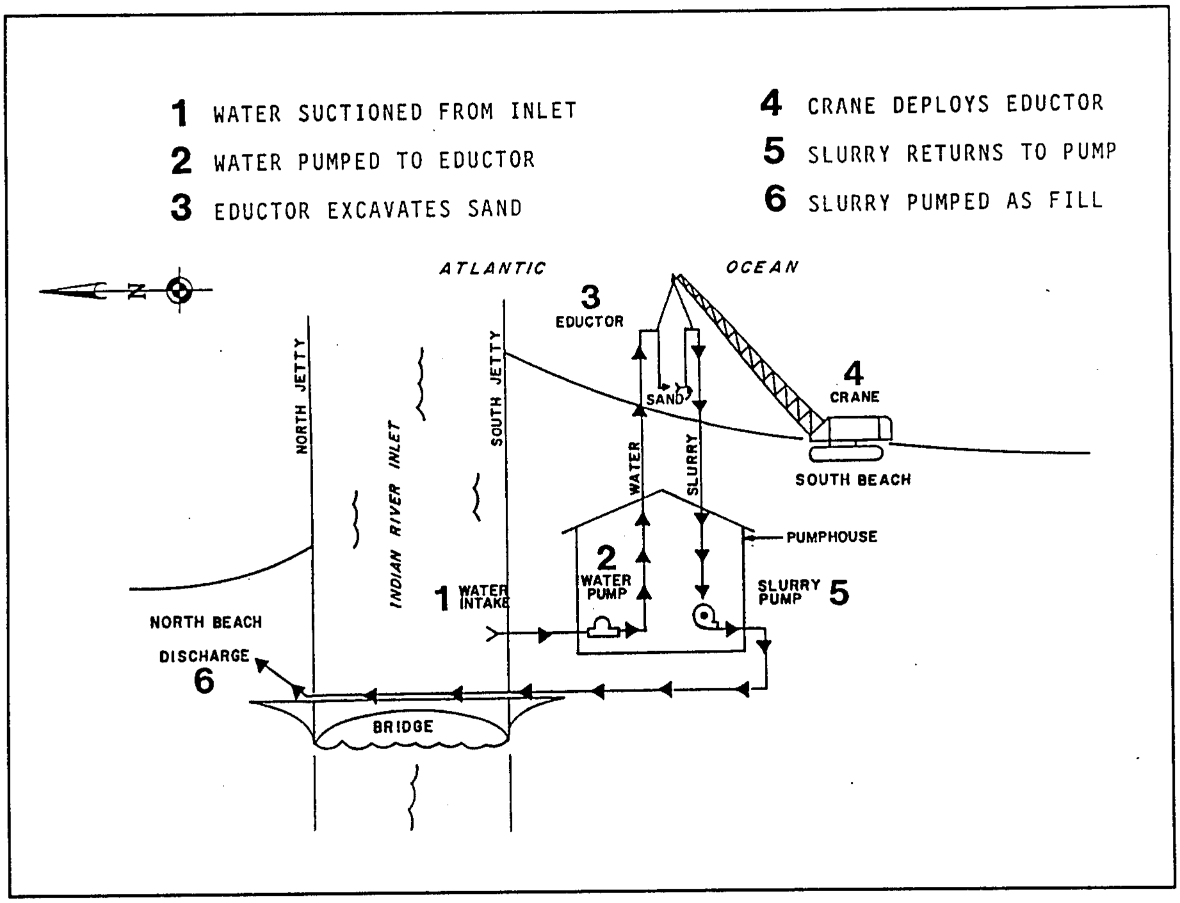


Figure 6. ITI bypass plant system layout

The bypass system is operated on a 5-days-per-week schedule during the period between Labor Day and Memorial Day. Because of the heavy recreational use of the adjacent beaches during the summer months, bypassing is restricted to the off-season.

Three persons operate the system, the primary operator, assistant operator, and crane operator. Bypassing operations typically create craters approximately 18 ft deep with 1:1.5 side slopes resulting in crater widths of 48 ft (14.6 m) and volumes of 400 yd^3 (305.8 m^3). Generally a trench approximately 150 ft (45.7 m) long can be created before requiring movement of the crane. Normal operating procedures were used during the eductor testing period.

The bypass plant began operation in February 1990, and through the first 4 years (Feb 90-Feb 94), 348,000 yd^3 (266,000 m^3) of material was transferred, thereby successfully performing the plant's mission of protecting the bridge approach north of the inlet. The average production rate during that time was approximately 290 yd^3/hr (221.7 m^3/hr). The ability of the bypass plant to protect the north beach was severely tested during the winter of 1991-92 when two northeaster storms struck the north Atlantic coast. The Lewes, DE, tide gauge (approximately 13 miles (20.9 km) to the north) recorded a maximum water level (1.86 m) of 6.1 ft National Geodetic Vertical Datum (NGVD) during the 1991 Halloween Storm (30-31 October) indicating a 20 percent chance of recurrence. On 4 January 1992, a short-duration northeaster produced a water level of 7.4 ft NGVD (4-percent chance of recurrence). Both of these storms caused severe beach erosion along the Delaware coast; however, bypassed sand combined with remnant beach fill accounting for over 300,000 yd^3 (229,400 m^3) of material north of the inlet, prevented any damage to the Route 1 approach (Clausner et al. 1992).

Grain size is an important aspect of the performance of a sand bypassing system. Grain size characteristics for the sand being bypassed at IRI are shown in Figure 7. The d_{50} is 0.25 mm. The specific gravity of the sand is 2.65 (i.e. quartz sand). During some periods of the year, deposits containing considerable amounts of pea-gravel-sized material (d_{50} of about 10 mm) are bypassed by the system.

Eductor Test Objectives

The field deployment tests conducted at the Indian River Inlet bypass plant were intended to test the DRP eductor in actual working conditions and compare its performance with that of the existing IRI eductor over an extended period of time. Clausner et al. (1994) discuss previous controlled tests conducted in a gravel pit comparing the DRP and IRI eductors in their ability to work in specific debris conditions. The bypass tests at IRI described in this paper utilized each eductor deployed in actual bypass operations over a several-month period of time. Because the DRP eductor was specifically

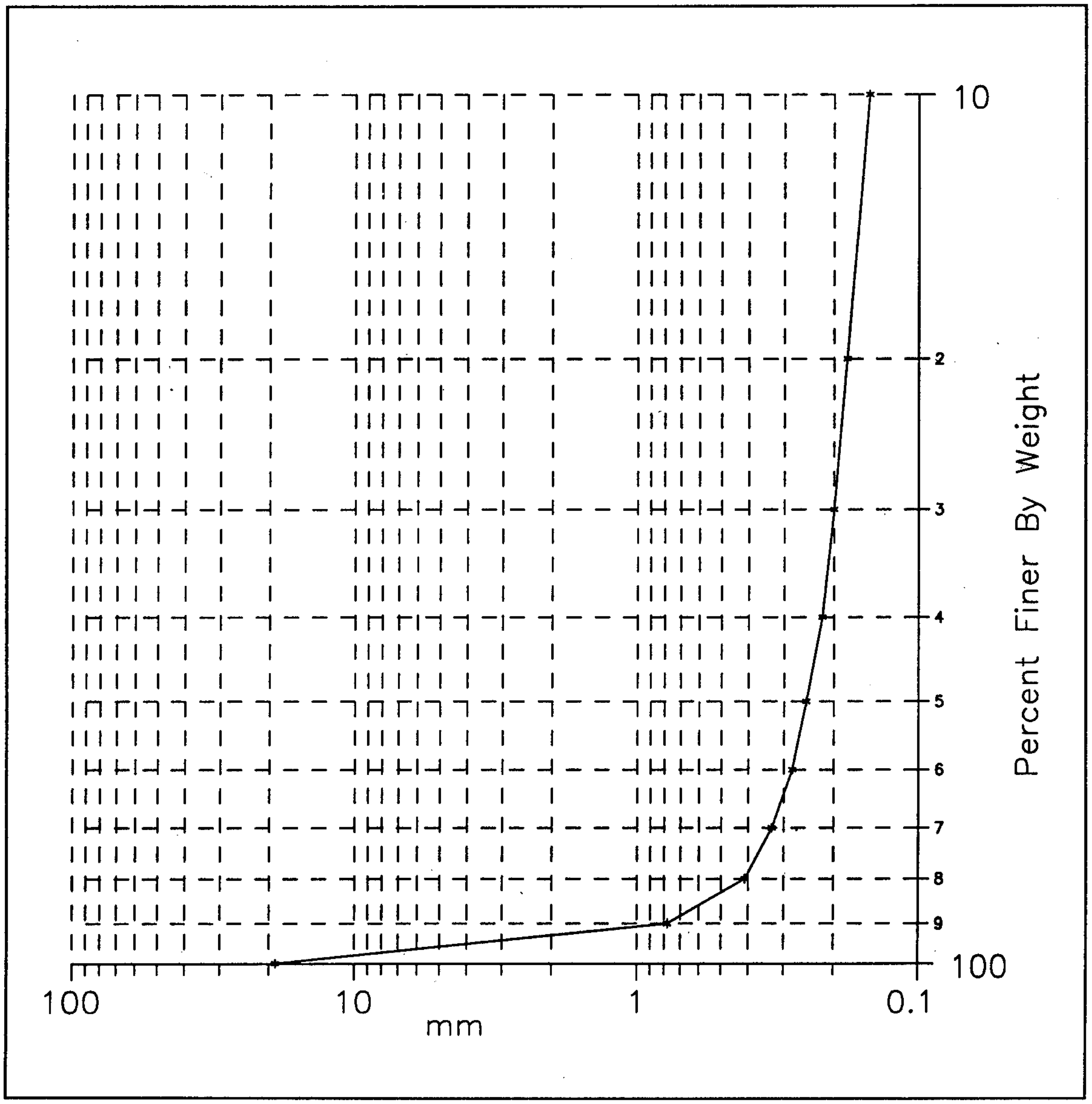


Figure 7. Grain size distribution curve for sand from the south shore of IRI

designed to operate in high debris conditions, two fundamental design differences (fluidizer arrangement and an inlet grate) existed that had the potential to affect production performance. Parameters such as short and long-term production rates, percent solids, slurry velocity, and various pressures were measured throughout plant operations for both eductors for use in overall performance comparisons.

Another objective of the IRI bypass tests was to determine the deployment capabilities for the DRP eductor. The IRI bypass plant operates with a crawler crane that strategically places the eductor in locations most desirable for bypassing. The DRP design was intended to be deployed from a fixed location, most likely from a pier, similar to the bypass plant at the Nerang River

Entrance, Australia. As noted earlier, the DRP eductor was modified for testing purposes. The extra weight and frame-generated inertia were expected to make normal crane deployment at Indian River Inlet somewhat more difficult (Figure 8). However, the comparison tests provided a qualitative impression of a non-fixed deployment.

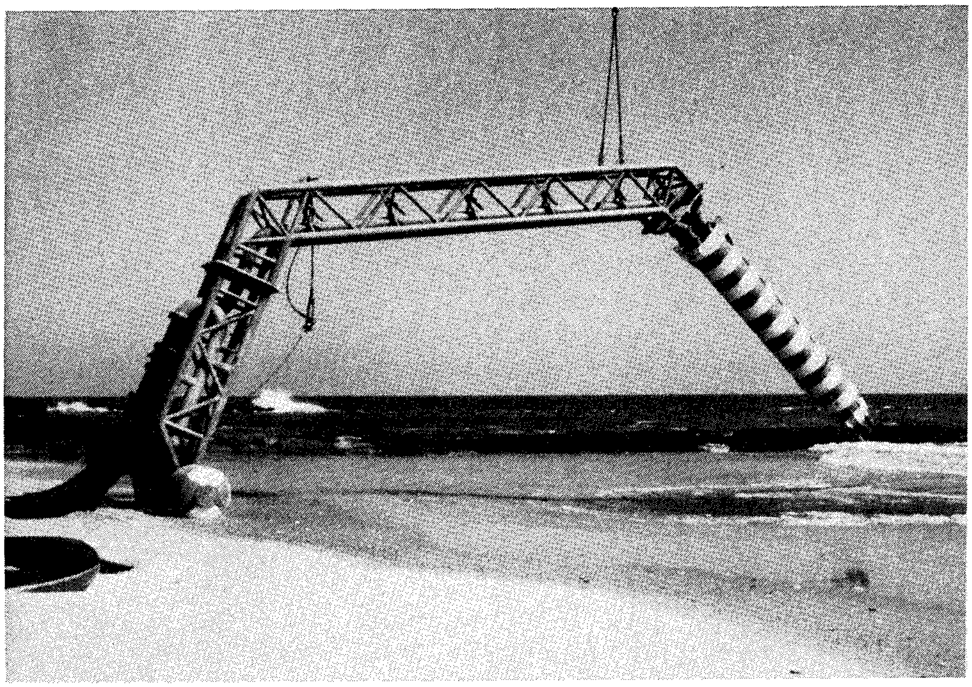


Figure 8. DRP eductor deployed at IRI

Data Collection Equipment and Procedures

To measure the performance of each eductor, the bypass plant was instrumented to record the pressures, densities, and velocities that are measured and displayed under normal operating conditions but not recorded. Pressures were measured by transducers located at the suction and discharge sides of the booster pump and the motive water supply pump. Density and velocity of the slurry in the discharge line were measured to determine the amount of material being discharged.

All data were gathered using gauges and meters already in place at the bypassing plant to aid in its operation. These gauges and meters were capable of providing or were adapted to provide an electrical current proportional to the gauge or meter reading. A Texas Nuclear density meter, consisting of a radioactive source and a detector located on opposite sides of the pipe, was attached to the discharge line. The density meter measures slurry specific gravity (or percent solids by weight of the slurry). Just downstream of the density meter an acoustic Doppler velocity meter was also mounted on the discharge line.

Pressure, density, and velocity data were recorded using a personal computer (PC) equipped with an Analog Devices RTI-815 board capable of transforming up to 32 channels of analog voltage readings into digital data. The data for the acquired channels are scaled to engineering units by linear calibrations, displayed on the PC monitor and saved to an output file. A scan of all channels was made once each second in a burst mode. Data displayed on the PC screen were updated every 3 sec and data were written to the output file every 30 sec. Data displayed on the screen and written to the output file represent the average of the 1-sec readings taken since the last screen update for the video display or since the last write to the output file for the saved data.

Each channel used was calibrated by recording the voltage displayed and the corresponding engineering value for that channel measured with an independent gauge or meter. As an example, to calibrate a channel for pressure data, the voltage on the channel would be recorded at several different pressures as measured by an independent pressure gauge. This information was then used to determine a linear scaling factor and an offset. The engineering value displayed and saved is computed by taking the reading in volts and multiplying it times the scaling factor (in engineering units/volts), and then adding the offset.

Of the 32 channels available on the A to D board, 8 were used. Channels 1 through 8 were used to display and record the slurry velocity, percent solids, production rate, slurry specific gravity, supply pump pressure, booster pump suction, booster pump pressure, and supply pump suction, respectively. Production in terms of in situ cubic yards of material was calculated knowing the density of the sand particles and assuming a 40-percent porosity for the in situ sand. Each day's cumulative production up to the time of each data write was summed and the accumulated production was recorded as a ninth channel of data. Data for each day of operation were saved in a separate computer file for later analysis as described in the following section of this report.

Field Tests

The comparison tests were conducted at the IRI sand bypassing plant from October 1992 through May 1993. Some tests were also conducted during the spring of 1992, but results were questionable due to problems with the instrumentation. Instrumentation was repaired in September 1992.

In general, there was one eductor test run for each day of bypassing operations. However, on occasion, two test runs were conducted in one day when the need for system maintenance (e.g. repositioning discharge pipe) caused the bypassing plant to be shut down temporarily. A total of 16 DRP eductor test runs were available for analysis between mid-October 1992 and early February 1993. The dates and duration of operation for each of the 16 DRP test runs are included in Table 2. Notations "A" and "B" differentiate multiple test runs on 1 day. Only run "B" was used from 20 Oct 1992 because of a computer logging problem during run "A." A total of 26 IRI eductor test runs were

Table 2
DRP Eductor Operation Dates and Times

Run	Date	Duration (HH:MM:SS)	Run	Date	Duration (HH:MM:SS)
1	20 Oct 1992 (B)	1:56:24	9	19 Nov 1992 (B)	2:52:48
2	21 Oct 1992	3:45:36	10	30 Nov 1992	0:48:00
3	22 Oct 1992	4:04:12	11	8 Dec 1992	4:55:48
4	26 Oct 1992	5:06:00	12	5 Jan 1993	6:14:24
5	27 Oct 1992	6:16:48	13	7 Jan 1993	1:01:12
6	16 Nov 1992	3:23:24	14	8 Jan 1993	0:31:48
7	17 Nov 1992	6:18:36	15	29 Jan 1993	4:43:12
8	19 Nov 1992 (A)	2:19:48	16	1 Feb 1993	5:16:48

available for analysis from between mid-February 1993 and mid-May 1993. The dates and duration of operation for each of the 26 IRI test runs are included in Table 3.

Table 3
IRI Eductor Operation Dates and Times

Run	Date	Duration (HH:MM:SS)	Run	Date	Duration (HH:MM:SS)
1	10 Feb 1993	0:27:36	14	23 Mar 1993	5:06:36
2	17 Feb 1993	1:36:36	15	24 Mar 1993	1:46:12
3	18 Feb 1993	1:39:36	16	29 Mar 1993	4:58:48
4	19 Feb 1993	3:28:48	17	30 Mar 1993	3:04:12
5	24 Feb 1993	1:42:36	18	19 Apr 1993 (A)	4:04:12
6	25 Feb 1993	4:36:36	19	19 Apr 1993 (B)	0:50:24
7	26 Feb 1993	2:34:48	20	21 Apr 1993	6:15:00
8	2 Mar 1993	5:10:48	21	23 Apr 1993	3:56:24
9	3 Mar 1993	3:27:00	22	24 Apr 1993	0:12:36
10	17 Mar 1993	3:21:36	23	28 Apr 1993	2:51:00
11	18 Mar 1993	5:55:48	24	29 Apr 1993	3:28:12
12	19 Mar 1993	0:42:36	25	3 May 1993	2:19:48
13	20 Mar 1993	2:37:48	26	10 May 1993	1:10:48

Data Collection

As previously noted, several parameters were measured during the eductor tests to be used in examining eductor performance. These parameters included: time, slurry velocity (feet per second), percent solids (by weight) of slurry, production rate (cubic yards per hour), specific gravity of slurry, motive pressure (pounds per square inch), pressure at booster pump intake (pounds per square inch), booster pressure (pounds per square inch), supply suction (pounds per square inch) and accumulated production (cubic yards).

Raw data were collected continuously with 30-sec averages reported. These 30-sec averages were used to calculate both 1-min and 5-min averages of all parameters. Initially, time series curves of the 1-min and 5-min average production rates were generated to observe individual qualitative productions. Figure 9 is a sample time series plot showing production rate, booster pump intake pressure, and booster pressure for a DRP eductor test run.

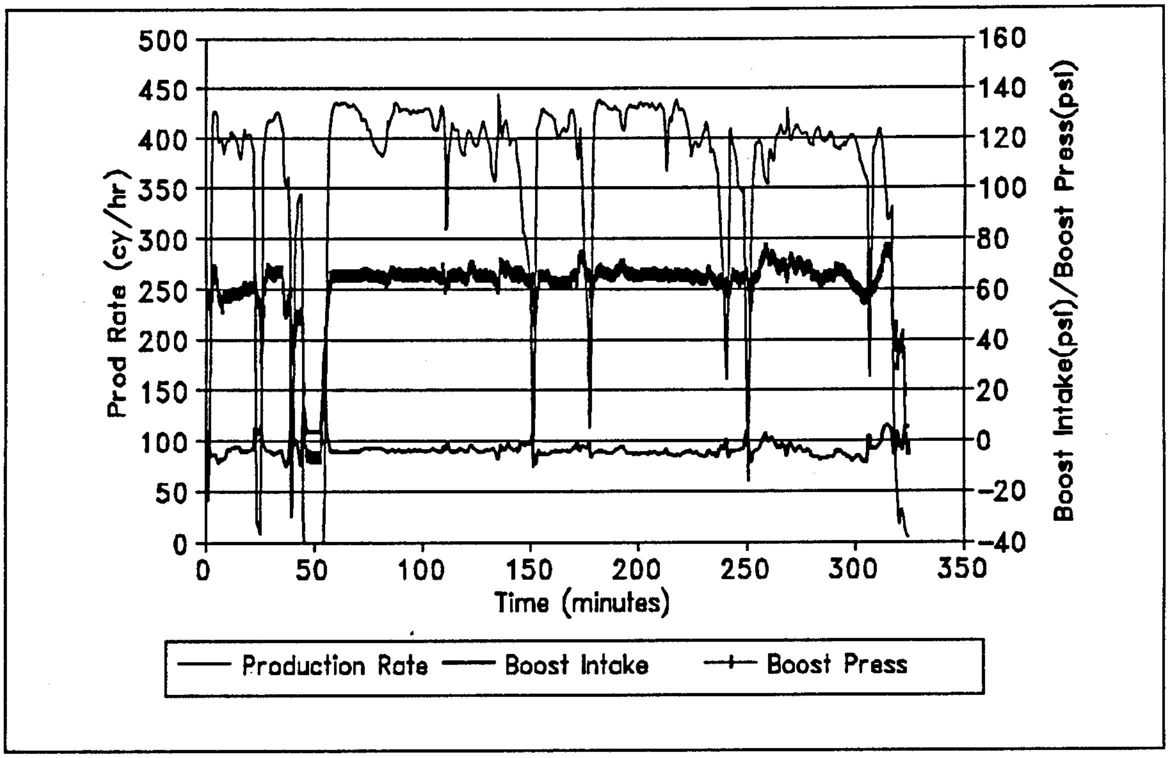


Figure 9. DRP eductor sample time series plot from test run of 1 Feb

Each of these parameters was examined to provide insight into the relation between eductor performance, system components, pressures, and material properties. The most direct way to compare eductor performance is to study the respective DRP and IRI production rates. To facilitate performance comparisons, average daily (test-run) production rates were calculated for both eductors, rather than examining the individual 1-min or 5-min averages in

Figure 9. Average daily production rates were calculated by summing the accumulated volume (cubic yards) of material bypassed during each test run and dividing by the duration (hours) of pumping for each test run. This average production rate is therefore more easily utilized in inter-comparison of eductor performance.

Factors that may have had an impact on eductor performance or influence comparison analyses were also examined and include: test run duration, relative number of test runs for each eductor, booster pump operation, waves, water levels and physical and operational parameters of the bypass plant. The average daily production rates for each eductor were compared based on these factors and are discussed in Chapter 4.

4 Analysis and Results

Production Rates

Average daily production rates, as described above, were calculated for each test run. The average daily production rates for each eductor were sorted by test run duration and plotted as bar charts in Figures 10 and 11. For the DRP eductor, the four largest production rates are associated with durations less than or equal to 200 min (≈3.3 hr). Similarly, for the IRI eductor, the four largest production rates are associated with durations less than or equal to 100 min (≈1.6 hr). These short-duration production rates illustrate the dependence of production on duration. Intuitively one would expect the first 45 min to 1 hr of operations, when the eductor is excavating the initial crater (volume of approximately 500 yd^3), to have a high production rate as sand freely flows to the eductor. After the initial crater is excavated, other external factors, primarily wave height or tide level, can impact the rate additional sand is supplied to the crater. The impact of these two factors is discussed in a later section.

Overall, Figures 10 and 11 indicate that there is less variability in production for the DRP eductor than for the IRI eductor. Maximum and minimum production rates vary from 428 yd^3/hr (327.2 m^3/hr) to 348 yd^3/hr (266.1 m^3/hr) for the DRP eductor and 433 yd^3/hr (331.1 m^3/hr) to 153 yd^3/hr (117.0 m^3/hr) for the IRI eductor. When considering all durations, almost all (94 percent) of the DRP eductor production rates are above 350 yd^3/hr (267.6 m^3/hr), while only half (50 percent) of the IRI eductor production rates exceed this rate. Similar results are found when only the longer durations are examined, those greater than or equal to 250 min (4.2 hr). At these durations, 88 percent of the DRP eductor production rates exceed or equal 350 yd^3/hr (267.6 m^3/hr) as compared to only 50 percent of the IRI eductor production rates.

Quantitative comparisons support the qualitative impression obtained from inspection of the production rate figures (Figures 10 and 11) that the DRP eductor outperformed the IRI eductor in average daily production. However, because the eductors were not tested simultaneously, other external factors may have had an influence on production differences.

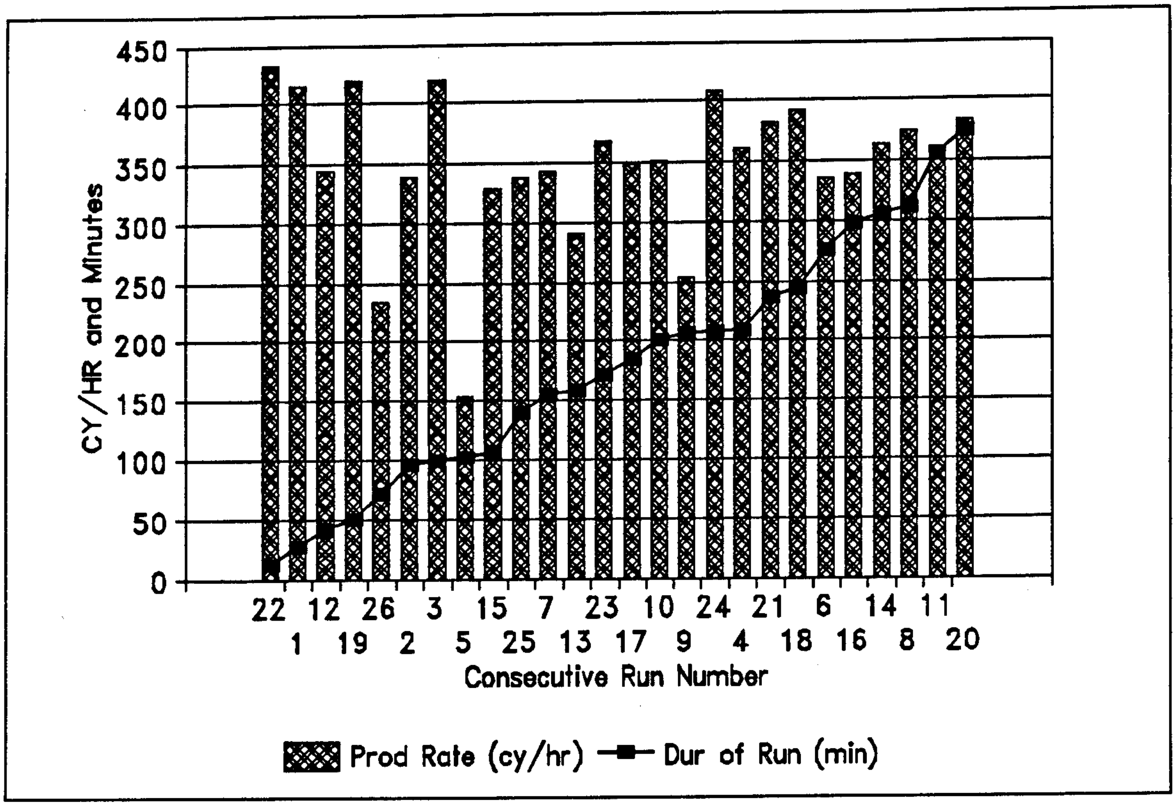


Figure 10. Average daily production rates for IRI eductor (duration sorted)

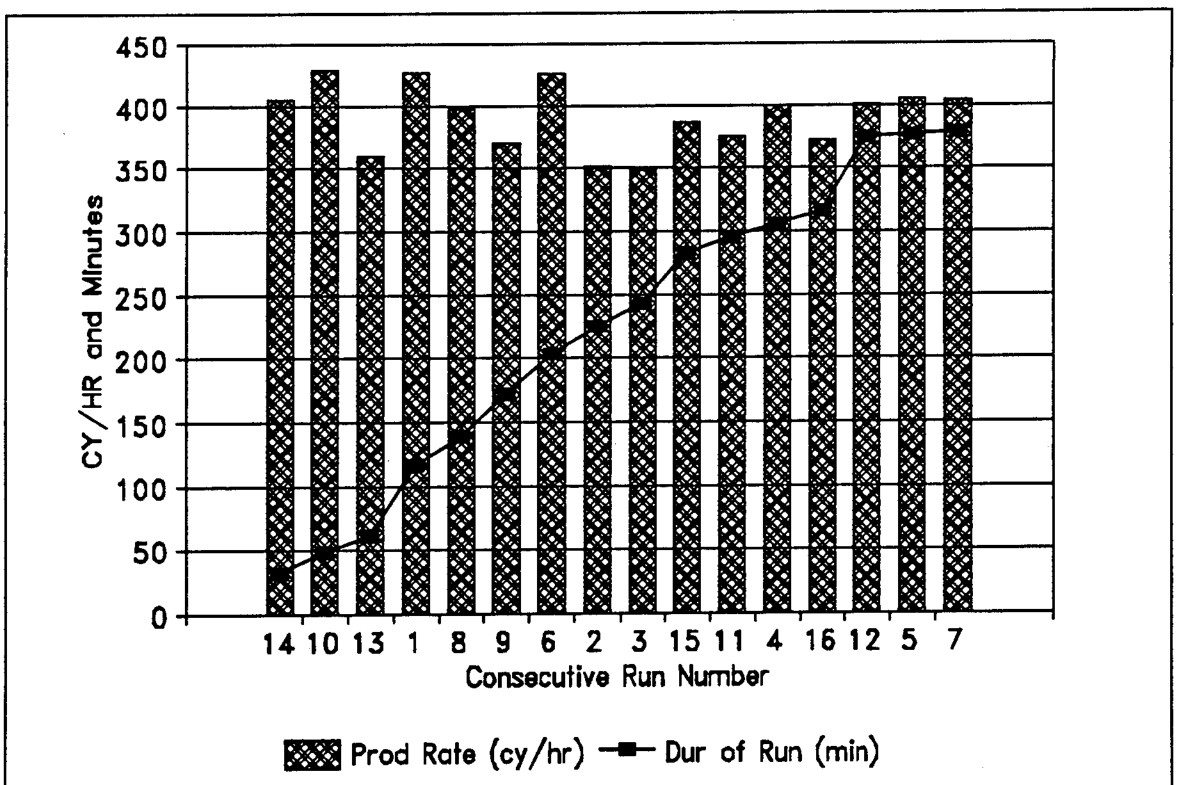


Figure 11. Average daily production rates for DRP eductor (duration sorted)

The difference in the number of test runs for each eductor (16 for DRP and 26 for IRI) could contribute to a statistical bias that may influence the analysis. To address this issue, an overall average production rate was calculated for each eductor. This total overall average was determined by dividing the total test run volumes for the DRP and IRI eductor (23,200 yd^3 (17,737.7 m^3) and 27,100 yd^3 (20,719.4 m^3), respectively) by the total duration of operation for each eductor (59.6 hr and 77.4 hr, respectively). This average results in overall production rates of 389 yd^3/hr (297.4 m^3/hr) and 350 yd^3/hr (267.6 m^3/hr) for the DRP and IRI eductors, respectively, indicating an approximate 11-percent increase in production rate for the DRP eductor.

The relative stability of the DRP's production versus the stability of the IRI's production can be examined by normalizing the individual test run production rates with each eductor's total average production rate. This weighted average daily production (WADP) is plotted in Figures 12 and 13 for each eductor, respectively.

Following a similar approach as described previously for all durations, approximately 56 percent of the DRP WADP rates were greater than or equal to 1.0 (i.e., production ≥389 yd^3/hr (297.4 m^3/hr)), while 58 percent of the IRI eductor WADP rates were greater than or equal to 1.0 (i.e. production ≥350 yd^3/hr (267.6 m^3/hr)). For durations greater than 250 min, 57 percent of the DRP eductor WADP rates were greater than or equal to 1.0 as compared to 50 percent for IRI eductor WADP rates. These results indicate that even though the number of test runs differed for each eductor, the individual eductors performed very similarly with respect to their own average. Thus, there appears to be no significant statistical influence from the number of test runs, which would lead to biased results.

To provide greater confidence that the production differences measured are actually due to the differences between the eductor's physical attributes (grates, intake chamber dimensions and geometry, fluidizers, etc.), other factors that could contribute to the differences were examined. Areas of possible influence are (a) the amount of energy available to the eductor to entrain sand (a function of both motive and booster pump pressures); (b) the efficiency with which sand entrained by the eductor is pumped to the downdrift beach (primarily a function of the booster pump pressures); and (c) the speed or ease with which sand is provided to the eductor (a function of the waves and water levels on crater refilling). The motive water pump that supplies water to the eductors provides the energy that is used to entrain the sand bypassed. The motive water pump operates at a very consistent pressure of about 150 psi (1,034.2 kPa) and consequently it has little impact on the variance in production rates. The booster pump is the primary force moving the bypass slurry (it also impacts entrainment efficiency), and its consistency of operation could affect eductor production rates. The booster pump was operated by either maintaining constant rpm throughout the pumping cycle or by periodically adjusting the pump rpm to adjust suction and discharge pressure to optimize pumping performance. Without knowing which procedure each pump operator utilized, a comparison of production rates based on operator work schedule

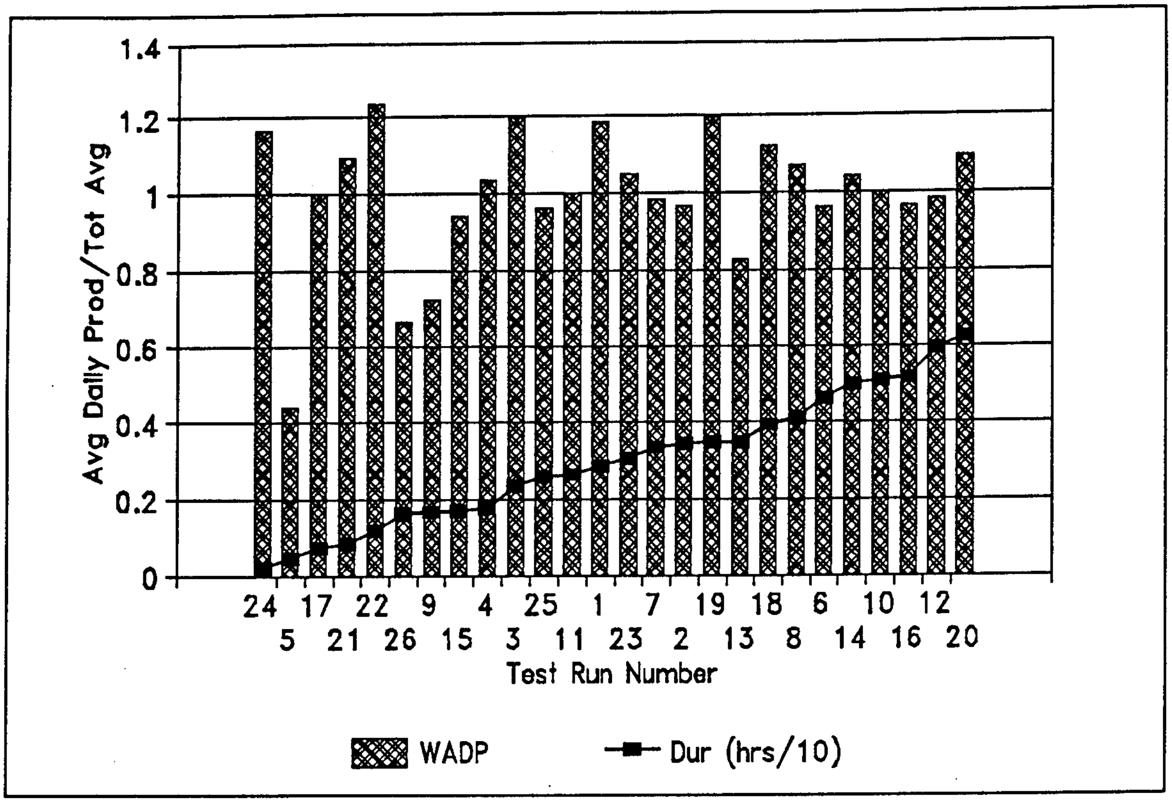


Figure 12. WADP rates for IRI eductor

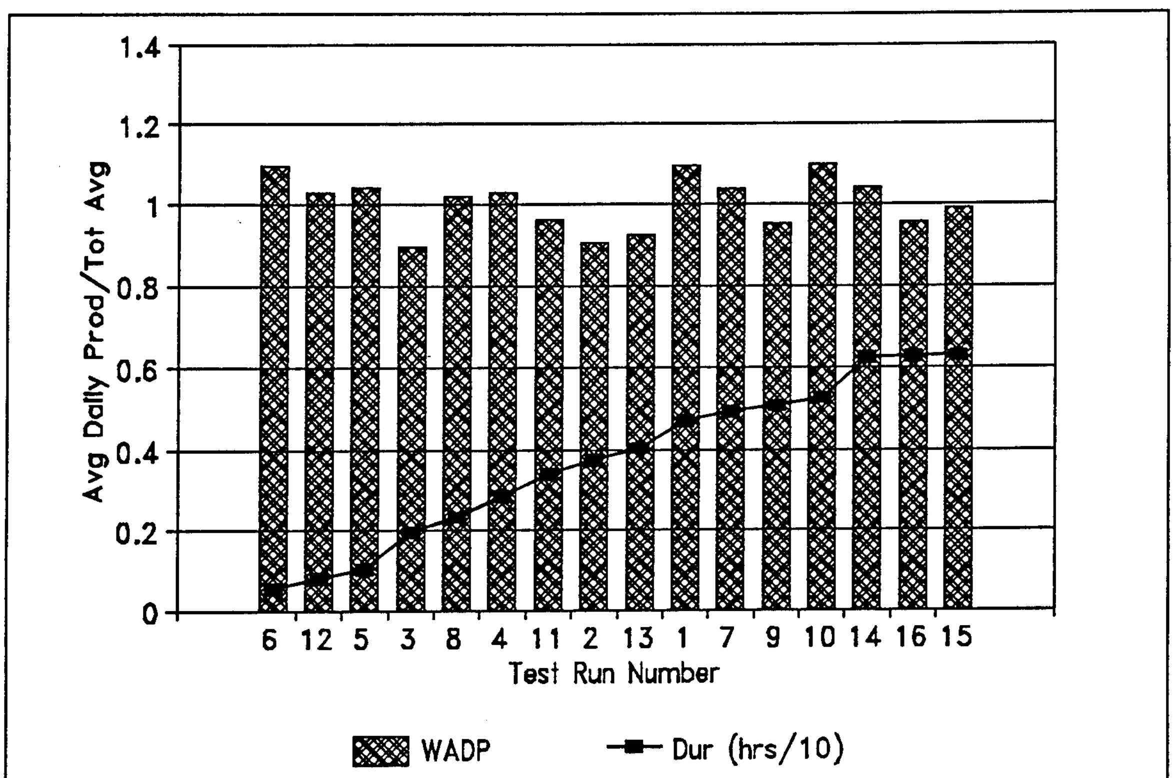


Figure 13. WADP rates for DRP eductor

was conducted. Booster pump operators varied for each eductor between "operator A," "operator B," or a combination of both operators. The average daily production rates shown in Figures 10 and 11 were regrouped according to booster pump operator and plotted in Figures 14 and 15. These figures show that no discernible pattern of difference existed between operators A and B with either eductor other than a greater production variability for operator A with the IRI eductor.

Waves and water levels during bypassing operations may also have influenced production rates of the eductors by adding sand to the crater at a faster or slower rate depending on the conditions during operation. Water level and wave height data were examined from the Coastal Engineering Research Center (CERC) wave gauge located in 30 ft (9.1 m) of water approximately 6 miles (9.7 km) north of Indian River Inlet at Dewey Beach, DE. Wave heights were recorded as H_{m0} (energy-based significant wave height) for the 30-ft (9.1-m) depth. Bar charts showing production rates similar to those previously shown were developed using the wave height to sort by, and no significant differences between eductors were observed.

Water levels were estimated from the CERC wave gauge record to determine what part of the tidal stage--high, high to low, low, or low to high--the bypass plant was operating in for each test run. National Oceanic and Atmospheric Administration tide tables were also referenced to verify times of peak highs and lows. Production rates for each eductor based on groupings of water level stage are shown in Figures 16 and 17. Groups are defined as follows:

a. L-m (rising tide from low to mid-tide).

b. m-H (rising tide from mid-tide to high).

c. H-m (falling tide from high to mid-tide).

d. m-L (falling tide from mid-tide to low).

For the DRP eductor, the most consistently large production rates are during m-H tide cycle. The lowest production rates occurred during cycles m-L and L-m. For the IRI eductor, the most consistent production rates were on rising tides (m-H) through falling tides (H-m). The greatest variability occurred during falling (m-L) and rising (L-m) tides. In both cases, the eductors demonstrated the most consistent performance during the m-H and H-m tide cycle. The influence of waves and water levels on performance was similar for both eductors, thereby indicating no statistical advantage for either eductor type.

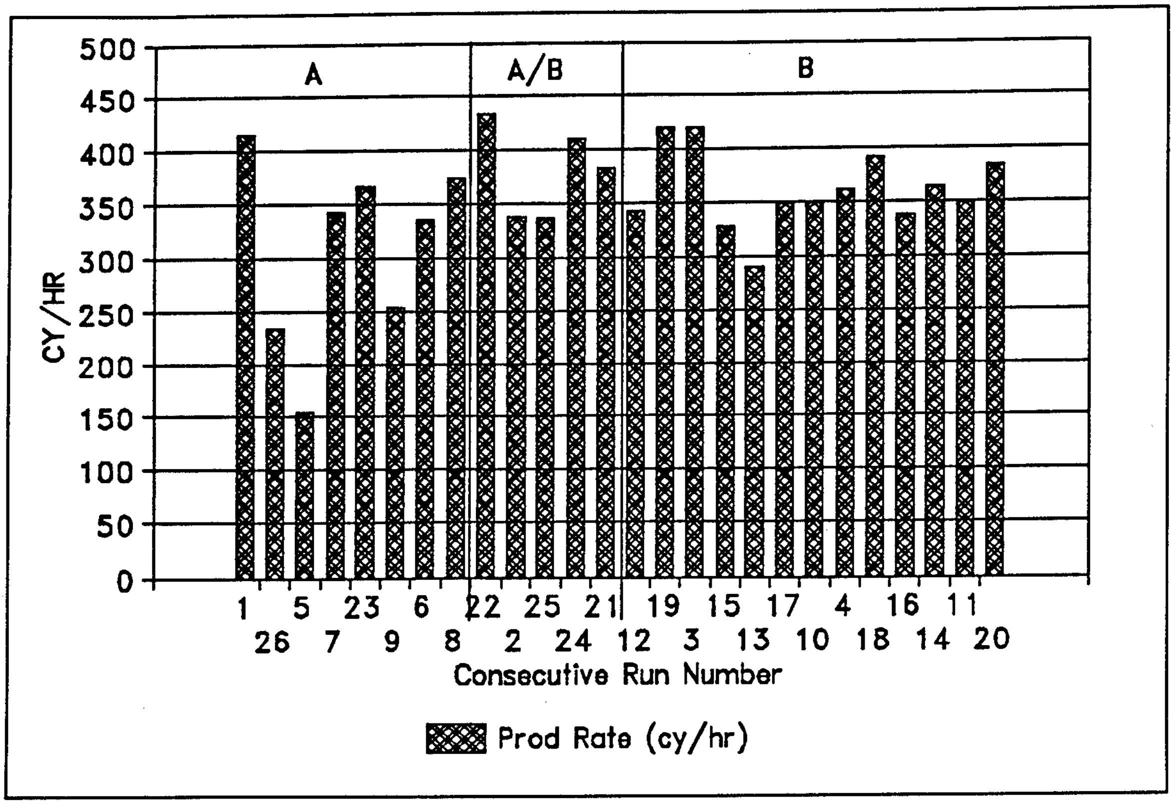


Figure 14. Operator-sorted average daily production rates, IRI eductor

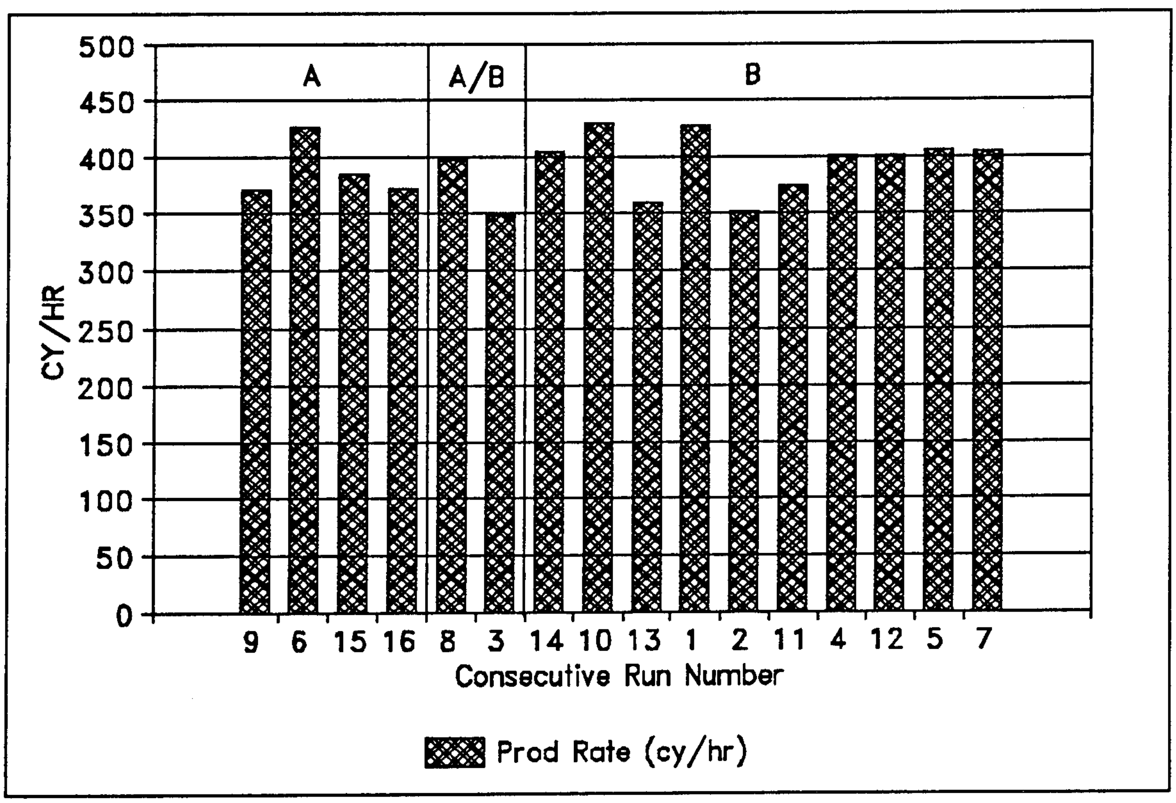


Figure 15. Operator-sorted average daily production rates, DRP eductor

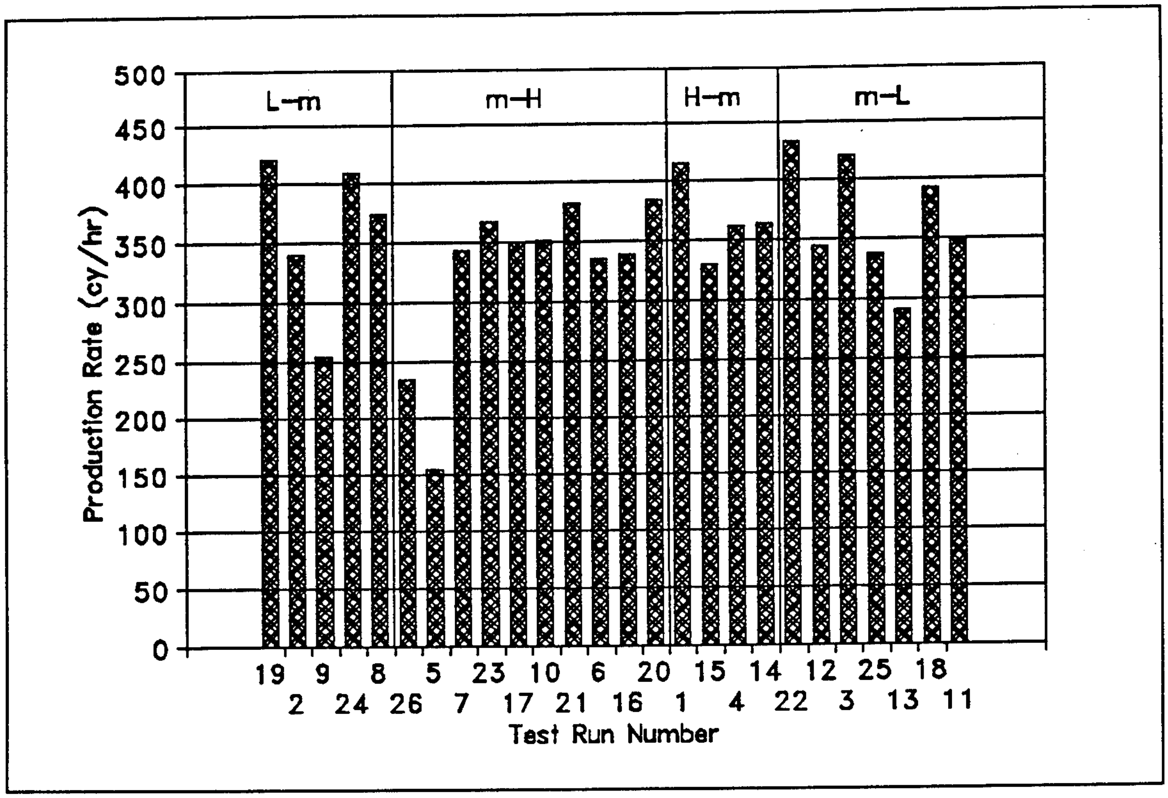


Figure 16. Water level-sorted average production rate, IRI eductor

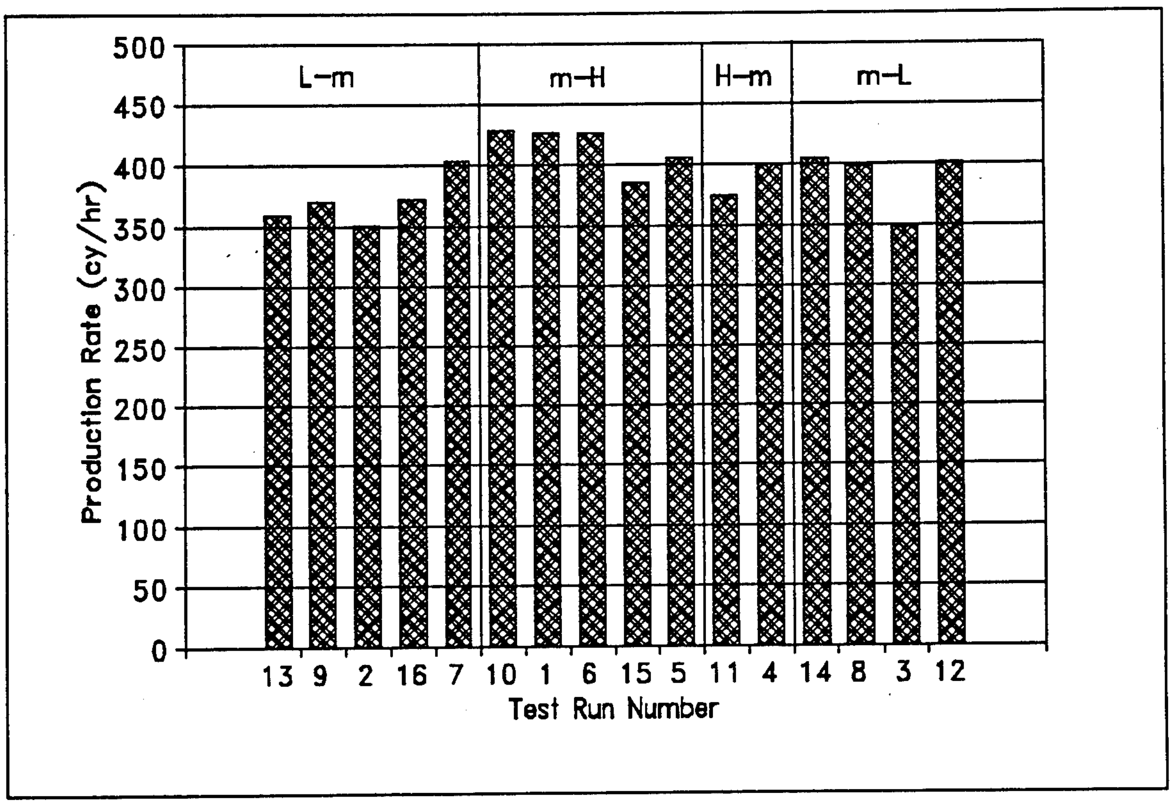


Figure 17. Water level-sorted average production rate, DRP eductor

Physical/operational parameters associated with the bypass plant itself could potentially impact production. Differences in the overall discharge pipeline length between eductor test runs could have caused differences in production due to increased pressure head requirements. At IRI, the discharge pipeline travels approximately 400 ft (121.9 m) westward from the pump house, then north for 400 ft (121.9 m) along the railing of the Route 1 bridge across the inlet, then northeast for between 500 and 1,500 ft (152.4 and 457.2 m) to the downdrift north beach. Depending on the desired discharge location, overall pipeline length can vary from 1,300 ft to 2,300 ft (396.2 m to 701.0 m). Bypass plant staff indicated that throughout the comparison tests, the discharge line was held relatively constant at between 1,800 and 1,900 ft (548.6 and 579.1 m). Because the pipeline was essentially constant length, no relative production differences should be expected due to discharge line length.

The nature of this comparison test was to compare production rates associated with two eductors having schematically different designs. Both eductors, however, operate with the same principle--a water jet entrains fluidized sediment which is then transported to a mixing chamber before being discharged. One constant in both designs is the nozzle through which the water jet is formed. In theory, different sizes of nozzles could change the water jet making it more or less efficient. In this case, the IRI eductor had a nozzle diameter of 65 mm while the DRP eductor nozzle was 70 m in diameter. While this difference would theoretically result in different nozzle flow rates, its effect compared to some of the previously mentioned factors would be negligible.[1]

Deployment/Retrieval

As expected, the extra weight and inertia associated with the DRP eductor, truss, and roller combination made it more difficult to maneuver than the IRI eductor. While the DRP eductor was sometimes deployed as designed with the rollers acting as a pivot point (Figure 8, page 22), often the operators found it easier to completely suspend the eductor using the two lift lines.

---

1 Personal Communication, 1994, Johnny Green, President, Standard Gravel Company, Franklinton, LA.

5 Conclusions and Recommendations

A number of specific conclusions directly relate to the eductor tests performed at IRI. However, as noted in Chapter 1, the "Improved Eductors for Sand Bypassing Work Unit" has maintained a larger view of eductor-based bypassing and bypassing in general. Thus, this section provides more generalized bypassing recommendations for both eductors and submersible pumps.

Conclusions

The eductor tests conducted were primarily intended to determine if there were any significant performance changes associated with the newly developed DRP eductor. By examining production rates and various influencing factors, the performance of the existing IRI eductor was compared to that of the DRP eductor. Figures 10 and 11 indicated that the DRP eductor performed slightly better than the IRI eductor without considering other factors. An analysis comparing the number of test runs for each eductor was conducted and showed that there was little or no difference in statistical weighing due to the difference in number of test runs for each eductor. Booster pump operator, waves, and water levels were also examined. Even though production rates did fluctuate with each factor, these fluctuations were generally consistent for both eductors. Finally, discharge line length and eductor nozzle were considered and it was determined that there was no practical relative difference associated with these physical/operational parameters.

Ultimately, all analyses support the findings initially presented in Figures 10 and 11 - in general, the DRP eductor outperformed the IRI eductor by approximately 11 percent. This increased production is probably most directly related to the perimeter fluidizer arrangement on the DRP eductor, which may have more efficiently entrained sand for entry to the pump and to the suction chamber geometry. Wakefield (1994) notes that in the shrouded (IRI) eductor (i.e. the IRI eductor) the material does not move uniformly up the shroud but tends to switch from side to side. This could contribute to the lower production rate and more irregular production.

One qualitative factor not included in the production analysis is the ease with which each eductor setup could be maneuvered. Bypass plant staff were more familiar using the crane to manipulate the IRI eductor system as opposed to the larger, heavier, and more awkward DRP eductor/deployment truss/roller combination. Thus it is probable that a slight additional increase in production may have been realized for a more easily maneuvered DRP eductor. For permanent use at a bypass plant like Indian River Inlet, the present DRP eductor could be made easier to handle by making some modifications. These would include removing the deployment truss/roller combination and modifying the upper end of the DRP eductor to accept the supply and discharge pipes by adding a curved steel pipe section similar to that used on the IRI eductor.

Finally, it should be reiterated that the intent of the DRP eductor design was for use in areas with large amounts of debris. The Indian River site is not indicative of an area with significant debris, so the true effectiveness of the DRP eductor in high debris areas was not tested. A follow-up test would be useful to verify that the DRP design is more effective in high debris areas. Tests by Clausner et al. (1994) indicate that the DRP eductor should be less impacted by debris consisting of stone and plastic and rubber materials.

Recommendations

The following recommendations are based on the authors' experience in sand bypassing gained over the past several years while working on the "Improved Eductors for Sand Bypassing" work unit and are not specifically related to tests presented in this report. Most of the following recommendations are specifically related to eductors, although some recommendations on submersible pumps and sand bypassing in general are included. Recommendations on eductor size, handling debris, and the proper location for bypassing plants are provided. Other references include Engineer Manual 1110-2-1616, "Sand Bypassing System Selection" (USACE 1991). Richardson (1991) provides an excellent and relatively short discussion on basic bypassing principles. Richardson and McNair's (1981) report on jet pumps also provides an excellent discussion of eductor bypassing concepts.

Eductor size. Eductor size refers to the entrance diameter of the mixing chamber which limits the size particle the eductor can pass. The minimum practical size eductor for a small-scale project (e.g. a small harbor), is an eductor with a 2.5-in.-diam (6.35-cm) mixing chamber. An eductor of this size would have a production rate of about 50 yd^3/hr (38.2 m^3/hr), and require a supply pump of about 60 hp (44.7-kW) operating through a 4-in. (10.2 cm) supply line. With a 40-hp (29.8-kW) booster pump, a discharge distance of about 1,000 ft (304.8 m) is possible. Such a system could easily be deployed from a small inflatable vessel and have both the supply and booster pump mounted on a trailer. This information is based on a paper by Prestedge and Bosman (1994) that describes a system used in South Africa.

The minimum practical eductor size for most open coastal projects is probably 6 in. (15.2 cm). While a smaller size may be acceptable from a production standpoint (e.g. the 4-in. (10.2-cm) eductors used at the Nerang River Entrance bypass plant), the potential for clogging for most sites dictates a minimum 6-in. (15.2-cm) mixer. A 6-in. (15.2-cm) mixer implies 10- and 11-in. (25.4- and 27.9-cm) supply and discharge lines, respectively, requiring a supply pump of about 300 hp (223.7 kW/kN). Booster pump horsepower will depend on the distance the sand must be bypassed. For a fixed plant requiring large amounts of material to be bypassed where debris is likely to be present, an eductor with a 9- or 10-in. (22.9- or 25.4-cm) mixer diameter is recommended.

Debris. The debris potential for a plant should be thoroughly investigated as to the type, size, and amount of debris present. Unfortunately, this may be difficult to predict prior to construction. Thus the safest course to pursue will be to assume that debris are present - if not natural debris, then manmade, unless there is strong evidence to the contrary. In other words, plan to deal with debris from the start. One solution is to make the eductor large enough to pass the vast majority of debris. However, it is likely that even larger debris will be present; therefore, it is absolutely essential to make the eductor easy to deploy and retrieve. In cases were large and heavy debris are expected, the ability to periodically clean out the area where the eductor is deployed with a clamshell or other device should be included in plant design. For a plant that deploys the eductor along the shoreline, e.g. the crane-deployed system at Indian River Inlet, this is a minor problem.

Location. The ideal location for a fixed bypass plant will depend on its design purpose. An eductor-based bypass plant that mines the updrift fillet similar to the one at Indian River Inlet is relatively simple to design. However, depending on how impervious the updrift jetty barrier is to longshore transport, it may only be able to capture a fraction (say two thirds) of the net longshore transport. Thus some sand will likely pass through the jetty system into the inlet making the bypass plant less effective from a navigation viewpoint (i.e. keeping an entrance channel open) and more effective in maintaining a suitable downdrift beach.

A shore-normal pier that extends across the surf zone like the one at the Nerang River Entrance or the one planned for the Port of Durban (Prestedge and Bosman 1994) has a much better chance of intercepting a larger portion of the littoral drift and thus can serve both as a system for maintaining navigation and for preventing downdrift beach erosion. Such a system will typically require multiple eductors (though a single eductor deployed from a crane that travels along the jetty is a possibility), and will generally be somewhat more complicated and expensive than a system that mines an updrift fillet.

Trying to maintain an entrance channel by placing eductors in the channel is not recommended. First, because an entrance channel is deeper than the surrounding area it is a natural sink for debris, making a difficult problem much worse. Second, supporting structures for deploying and retrieving the eductors (e.g., a pier) cannot be built in or immediately adjacent to the

entrance channel for obvious safety reasons. The eductors in an entrance channel will have to be placed at the end of long pipes that extend from outside the entrance channel. This makes deployment and retrieval of the eductors much more difficult because they and the associated pipelines have to be raised and lowered through many feet of sand. Also as noted the debris problem will likely make the need to service the eductors a regular occurrence. Therefore, if an eductor system is to be used to maintain an entrance channel, it will be most effective if it can be designed to capture the sand before it reaches the channel. The shore-normal pier with multiple eductors is the likely choice for such a system.

Note that for a small harbor, a portable eductor system deployed from a small boat is basically an inexpensive, easily operated, and safe dredge that can generally be operated by the locals. For large harbors with long entrance channels and complicated shoaling patterns, a dredge will remain the best option for maintaining the navigation channel at many locations.

Deployment/retrieval. Practical experience gained from working with the eductor and arched boom arrangement during the controlled tests in Louisiana (Clausner et al., in preparation) and during the tests conducted at Indian River Inlet indicate that a large crane (with a large rubber-tired, front-end-loader type vehicle for repositioning the supply and discharge lines) is a good combination for beach deployment of eductors when deep craters (say deeper than 12 to 15 ft) will be used. For shallower craters, a smaller crane or large excavator will likely be sufficient and may be sufficient for craters 12 to 20 ft deep. Prestedge and Bosman (1994) describe a hydraulically powered excavator that can traverse out into the surf zone that will be used as a platform to deploy a small eductor for trenching pipelines and mining heavy minerals.

For eductors deployed from a pier there are several options. A system similar to a beach mining operation could be used with a small crane or large excavator or even a manually operated crane used to deploy a single eductor. Managing the supply discharge lines would be the major problem. For a long pier (i.e. a wide surf zone) operating in an area of considerable transport, multiple fixed eductors probably make more sense. Use of a cased eductor with radial fluidizing jets similar to the DRP eductor should reduce pullout forces and make deployment and retrieval much easier. Eductors have also been successfully deployed in non-sand bypassing applications using a hose spooler (Wakefield 1992) and have been proposed for bypassing situations (Wakefield 1988).

Submersible pumps. As noted earlier, submersible pumps have been used successfully around locks (Neilans et al. 1993). These applications have been relatively small, aperiodic jobs removing fine sand with considerable amounts of silt where initial cost and the low number and simplicity of components (integrated power unit/hydraulic pump with small diameter hydraulic cables leading to the submersible pump) have been of prime importance. As noted in Clausner et al. (in preparation) submersible pumps are not recommended in coastal sand bypassing applications. The high amount of operator adjustments

required to maintain high solids contents and the potential for line plugging when dredging medium and coarser sand makes them less desirable than eductors. Also, the small portable eductor systems described by Prestedge and Bosman (1994) could provide an alternative to the submersible pumps around locks. However, the potential requirement for a booster pump and the handling requirement for the extra supply line may offset the advantage of the reduced potential for line plugging and higher solids contents particularly when dredging silty materials.

Acknowledgements

The tests described in this report would not have been possible without the assistance and cooperation of the State of Delaware, Department of Natural Resources and Environmental Control (DNREC) and the Philadelphia District, USACE. The authors appreciate the efforts of the senior DNREC administrators - Messrs. Robert Henry and John Hughes, and the bypass plant staff - Messrs. Kenny Melson, Jerry Hickman, and Jim Boyer. Their dedication and enthusiasm for this effort greatly improved the quality of the tests conducted and data collected. Philadelphia District staff (Messrs. Gus Rambo and Gary Rohn) were also instrumental in conducting these tests and the authors thank them for their support.

The DRP eductor contractor, Mr. Johnny Green of Genflo America and his European partner, Mr. Tony Wakefield, produced a quality product on time, within budget, and provided many other useful suggestions during this effort. Their contributions were much appreciated.

Finally, the authors would like to acknowledge the efforts of Ms. Sandra Staggs of WES' contract branch. A large part of the DRP eductor development, construction, and testing was done under contract. Ms. Staggs conducted these contracting aspects in a very professional manner.

References

Bisher, D. R., and West, F. R. (1993). "Jet pumps and fluidizers working together: The Oceanside experimental sand bypass system. *Proceedings of the 1993 Florida Shore and Beach Annual Beach Preservation Technology Conference*. St. Petersburg, FL.

Clausner, J. E. (1988). "Jet pump sand bypassing at the Nerang River Entrance, Queensland, Australia." *Proceedings, Beach Preservation Technology '88*. Florida Shore and Beach Preservation Association, Gainesville, FL, 345-55.

Clausner, J. E., Patterson, D. R., and Rambo, A. (1990). "Fixed sand bypassing plants--an update." *Proceedings, Third Annual National Beach Preservation Technology Conference*. Florida Shore and Beach Association, Tallahassee, FL, 249-64.

Clausner, J., Gebert, J., Watson, K., and Rambo, A. (1992). "Sand bypassing at Indian River Inlet, Delaware," *CERCular* Vol CERC-92-1, March 1992, Coastal Engineering Research Center, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Clausner, J. E., Welp, T. L., and Bishop, D. D. (1993). "Controlled tests of eductors and submersible pumps," *Dredging Research Technical Notes*, DRP-3-05, April 1993, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Clausner, J. E., Neilans, P. J., Welp, T. L., and Bishop, D. D. (1994). "Controlled tests of eductors and submersible pumps," Miscellaneous Paper DRP-94-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Jones, C. P., and Mehta, A. J. (1980). "Inlet sand bypassing systems in Florida," *Shore and Beach* 36(1), 27-30.

McNair, E. C. (1976). "A sand bypassing system using a jet pump." *Proceedings, Fifteenth Coastal Engineering Conference*, ASCE. 1342-60.

Moffatt and Nichol Engineers. (1990). "Experimental sand bypass system Oceanside Harbor, Oceanside, California, Phase II, Base Plan, Basis for Design," prepared for U.S. Army Engineer District, Los Angeles.

Neilans, P., Clausner, J., Corkern, C., and Coldiron, J. (1993). "Maintenance applications of a submersible pump on the Red River waterway," *World Dredging, Mining, & Construction*," September.

Prestedge, G. K., and Bosman, D. E. (1994). "Sand bypassing at navigation inlets: Solution of small scale and large scale problems." *Proceedings of the 7th Annual National Conference on Beach Preservation Technology.* Tampa, FL, Florida Shore and Beach Preservation Association.

Rambo, G., and Clausner, J. (1989). "Jet pump sand bypassing, Indian River Inlet, Delaware," *Dredging Research: Information Exchange Bulletin*, Vol DRP-89-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Richardson, T. W. (1991). "Sand bypassing." *Handbook of coastal and ocean engineering; Vol 2, Offshore structures, marine foundations, sediment processes, and modeling*. J. B. Herbich, ed., Gulf Publishing Co., Houston, TX, 809-28.

Richardson, T. W., and McNair, E. C. (1981). "A guide to the planning and hydraulic design of jet pump remedial sand bypassing systems," Instruction Report HL-81-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

U.S. Army Corps of Engineers. (1991). "Sand bypassing system selection," Engineer Manual 1110-2-1616, Washington, DC.

Wakefield, A. M. (1988). "Report on the application of jet pumps to sand by-passing," unpublished report, prepared under contract to the U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

__________. (1992). "Hybrid jet-centrifugal pump systems in dredging and sand bypassing." *Proceedings, XIIIth World Dredging Congress.* Bombay, 276-95.

__________. (1993). "Beyond shut-off--why the solids-handling jet pump stabilizes pipeline flow." *Proceedings, Hydrotransport 12.* Bruges, 37-56.

__________. (1994). "Sand bypassing by embedded jet pump hybrid systems." *Proceedings, Beach Technology '94.* Florida Shore and Beach Preservation Association, Tampa, FL.

Watts, G. M. (1962). "Mechanical by-passing of littoral drift at inlets," *Journal, Waterways and Harbors Division*, ASCE 88(WWI), 88-99.

Weisman, R. N., Lennon, G. P., and Clausner, J. E. (1992). "A design manual for coastal fluidization systems." *Proceedings of Coastal Practice '92.* ASCE, Long Beach, CA.

Weisman, R., Lennon, G., and Clausner, J. (1994). "A guide to the planning and hydraulic design of fluidizer systems for sand managment in the coastal environment," in preparation, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
November 1994

3. REPORT TYPE AND DATES COVERED
Final report

4. TITLE AND SUBTITLE
Improved Eductors for Sand Bypassing

5. FUNDING NUMBERS
WU 32474

6. AUTHOR(S)
Gregory L. Williams, James E. Clausner,
Peter J. Neilans

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Engineer Waterways Experiment Station
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

8. PERFORMING ORGANIZATION REPORT NUMBER
Technical Report DRP-94-6

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Corps of Engineers
Washington, DC 20314-1000

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

An eductor developed under the Dredging Research Program (DRP) was field tested at the existing sand bypass plant at Indian River Inlet, Delaware. Field measurements of slurry velocity, percent solids, production rate, slurry specific gravity, supply pump pressure, booster pump suction, booster pump pressure, and supply pump suction were made for this eductor and compared to analogous measurements of the existing Indian River Inlet (IRI) eductor. Though the DRP eductor was specifically intended for a fixed bypass plant with significant debris problems, the mobile Indian River Inlet plant proved to be a useful field test location because of existing instrumentation and similar hydraulic requirements for both eductors. Results showed that the DRP eductor outperformed the IRI eductor with an increased 11-percent production rate. Operational and environmental influencing factors were taken into consideration for each set of test runs and were shown to be either equal for each eductor or insignificant.

14. SUBJECT TERMS

Debris	Jet pumps
Eductors	Sand bypassing

15. NUMBER OF PAGES
44

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED		